REPORT RESUMES

ED 015 326 VT 004 159

EVALUATION OF CHANGES IN SKILL-PROFILE AND JOB-CONTENT DUE TO TECHNOLOGICAL CHANGE, METHODOLOGY AND PILOT RESULTS FROM THE BANKING, STEEL AND AEROSPACE INDUSTRIES.

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PUB DATE OCT 66
EDRS PRICE MF-$1.25 HC-$12.32 306P.

DESCRIPTORS- *TECHNOLOGICAL ADVANCEMENT, *JOB SKILLS, EMPLOYMENT PROJECTIONS, *STEEL INDUSTRY, *BANKING INDUSTRY, PRODUCTIVITY, OCCUPATIONAL INFORMATION, COMPARATIVE ANALYSIS, STATISTICAL ANALYSIS, JOB ANALYSIS, EMPLOYMENT QUALIFICATIONS, ADMINISTRATIVE POLICY, ELECTRONIC DATA PROCESSING, NUMERICAL CONTROL, AUTOMATION, FIELD STUDIES, *AEROSPACE INDUSTRY, EVALUATION TECHNIQUES,

THE MAJOR OBJECTIVE WAS TO TEST THE HYPOTHESIS THAT THE HIGHEST LEVELS OF MECHANIZATION AND AUTOMATION GENERALLY REQUIRE LOWER LEVELS OF SKILLS THAN EARLIER PRODUCTION SYSTEMS. A SECONDARY OBJECTIVE WAS TO DEVELOP AN INSTRUMENT CAPABLE OF GIVING UNBIASED PROJECTIONS OF THE MANPOWER IMPACT OF SPECIFIC ADVANCES IN PRODUCTION TECHNOLOGY. DEPENDENT VARIABLES WERE MAN-HOUR REQUIREMENTS PER UNIT PRODUCT AND REQUIRED SKILL LEVEL RATED ON A PRIVIOUSLY DEVELOPED SCALE. DATA FROM ACTUAL OBSERVATIONS OF PROCESSES, FROM COMPANY JOB ANALYSIS INSTRUMENTS, AND EMPLOYEE, COST, AND PRODUCTION RECORDS WERE COLLECTED INDEPENDENTLY FROM TWO FIRMS IN EACH INDUSTRY FOR WHICH AN OLD AND A NEW PROCESS WERE COMPARED -- BANKING, STEEL ANNEALING, STEEL GALVANIZING, AND AEROSPACE METAL MACHINING. ALL PAIRS OF PROCESSES SHOWED THE EXPECTED REDUCTION IN MAN-HOUR REQUIREMENT PER UNIT, AND IN ALL CASES INSTALLATION OF THE NEW PROCESS WAS JUSTIFIED IN TERMS OF HIGHER PRODUCTIVITY. MEAN SKILL LEVELS WERE INCREASED TO A STATISTICALLY SIGNIFICANT EXTENT IN ALL CASES EXCEPT METAL MACHINING WHERE THEY WERE REDUCED SIGNIFICANTLY. HOWEVER, THE CHANGES WERE SMALL IN ABSOLUTE TERMS. MANPOWER DEMAND INCREASES RESULTING FROM USING THE NEW PROCESSES WERE NOT BIG ENOUGH TO AFFECT THE LABOR FORCE. THEREFORE, OTHER SECTORS OF THE ECONOMY WILL HAVE TO FURNISH NEEDED EMPLOYMENT. THE APPENDIX, APPROXIMATELY 200 PAGES, CONTAINS PROCEDURES FOR CREATING THE INSTRUMENTS USED IN THE STUDY, RAW DATA, DATA ANALYSIS, AND JOB DESCRIPTIONS WITHIN THE FIVE CASES. (EM)

ED015326

EVALUATION OF CHANGES IN SKILL-PROFILE AND JOB-CONTENT DUE TO TECHNOLOGICAL CHANGE: METHODOLOGY AND PILOT RESULTS FROM THE BANKING, STEEL AND AEROSPACE INDUSTRIES,

U.S. Department of Labor Contract No. 81-04-05

HUMAN FACTORS IN TECHNOLOGY RESEARCH GROUP
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VT004159

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U.S. Department of Labor Contract No. 81-04-05
issued under the Manpower Development and Training Act, 1962

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October 1966

ACKNOWLEDGMENTS

The research team wish to record their gratitude for the extensive assistance and cooperation of the following firms:

Bank of America:	The Management, the ERMA Center and the Personnel Relations Department in San Francisco, the Berkeley Main Branch Office and the Berkeley ERMA Center, and the Branch Office in Truckee, California.
Wells Fargo Bank:	The Management, the Personnel Department, the Encoding, Account Service, and EDP Centers in San Francisco, the Berkeley Main Branch Office and the Branch Office in Tahoe City, California.
Kaiser Steel Works:	The Management, the Industrial Relations Division and the Industrial Engineering Department, Fontana, California.
Rohr Corp.:	The Management, the Organization Planning and Training Department, and the Machine Shop Planning Department, Chula Vista, California.
Lockheed:	The Bureau of Naval Weapons Representative at Lockheed Missiles and Space Co., and to the Management and the Manufacturing Department, Lockheed Corp., Sunnyvale, California.
C.W. Ritter Western Check Co.:	Redwood City Works, California.

Kaiser Aerospace and Electronics Corporation, San Leandro Works, California

Solar Division of the International Harvester Company, San Diego, California

and one further company which does not desire to be identified by name.

We are further indebted to the Public Relations Department of the U.S. Steel Corporation, Pittsburg, Pennsylvania for permission to reproduce illustrations 1-6 in Appendices II and III, from Camp, J.M. and Francis, C.B., The Making, Shaping and Treating of Steel, Pittsburgh, Pennsylvania, U.S Steel Co., 1964.

Professor J. R. Bright has kindly given permission to reproduce the Level of Mechanization scale from Automation and Management, Boston, Harvard Business School, 1958.

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SUMMARY OF METHODOLOGY AND CONCLUSIONS

A. Methodology

A new method has been developed for measuring the impact of selected advances in technology on the distribution of skills required in the direct labor force in manufacturing and service industries. Based broadly on the "direct productivity" studies conducted by the Bureau of Labor Statistics in the late 'forties and early 'fifties, the procedure as applied to a single process entails evaluating the manhours of direct labor expended per unit product at each of several skill levels, and thence computing skill-based productivity measures and mean skill level.

Established job-evaluation schemes used by firms for deriving basic pay rates providedthe essential data for assessments of skill-level, a quantitative skill-scale being obtained by grouping point scores for selected factors; the point scores for a single process fall into a distribution termed a "skill-profile". Mean skill-levels were computed from the skill-scale point scores multiplied by manhours per unit product and summed over all workers employed on the process. The standard deviation and range of skill-levels, and other relevant statistics were also computed. This enabled comparisons to be drawn between the skill-profiles obtained for two or more levels of production technology.

For the comparisons to reveal differences in manpower and skill requirements due solely to changes in process technology and not to changed product specifications or other irrelevant factors, it was found necessary to carefully select and control the case material. In particular the two (or more) processes were matched in respect of the dimensions, quality specifications and other relevant characteristics of raw materials and finished product. Furthermore, steps were taken to ensure that each process studied was in a steady state, and a criterion of two or more years' productive operation was applied to avoid confounding transient effects during the changeover period with more permanent steady-state effects.

A comparison between a single pair of processes matched as described above does not provide an estimate of random error (uncontrolled variation) such as is needed to test observed differences for statistical significance; this was obtained by replicating each matched-pair comparison in a different firm or organization, again matching the raw materials and product as closely as possible, and also technologies of the older and newer processes operated by the two (or more) firms or organizations.

When controlled data for two or more such pairs of processes have been obtained it becomes possible to test observed changes in mean skill-level for statistical significance by analysis of variance of the manhour data. Variations ("main effects") due to skill-level, technological level and firm are removed first, and the interaction between skill-level and technological level is then tested for significance against the three-way interaction between skill-level, technological level and firm. Thus fully quantitative conclusions can be drawn from a small number of sample observations, provided that a minimum of four matched processes are studied (i.e., two or more technological levels in each of two or more firms).

Estimates of the effect of technological change on diversity of job-content and on required levels of education, training, and on-the-job experience were obtained in parallel with the above data by enumerating job-types and evaluating required education and experience for each. While these supplementary data provide indications of trends in educational and training demands, etc., they are less readily quantified than data based on job-evaluation, and have been given a secondary place in this report.

B. Limitations and sources of uncertainty

The main source of uncertainty involved in extrapolating sample results obtained for specific processes by this method to the total "population" of like processes in order to estimate and/or project the future manpower and skill impact of specific kinds of technological change, lies in the discrepancy between total labor-time consumed and manhours expended in productive work. Particularly in the newer, more automatic processes, active work on the process may occupy only a comparatively small fraction (ranging upwards from 10%) of the total time the worker spends in the plant, the balance representing what may be termed "organizational slack". The slack may often be reduced or eliminated by rationalizing the physical layout of plant and centralizing control, and by combining jobs. To the extent that there is slack in a process studied, the manhours required per unit product may appear greater than they should be, and this implies that forecasts of required manpower and skills obtained by combining unit labor requirements with expected demand will be biassed upward. It has not so far proved possible to obtain quantitative estimates of this effect and to allow for it in the results.

The method described above has been applied to direct labor only. Because direct labor in most cases constitutes a large proportion (over 75%) of total labor per unit product, conclusions can be drawn from the results with little risk of invalidation by unobserved changes in indirect labor with technological change. While in principle there is no reason why the method described should not be extended to cover the complete labor force for a specific process, data on indirect labor is more difficult and time-consuming to obtain, due mainly to the diversity of jobs and activities involved, to the greater time-variation in manhours expended, and to the difficulty of assigning overheads to one process among many.

C. Substantive conclusions drawn from the sample

Four processes were studied in firms on the West Coast using the methodology outlined above,

Demand-deposit accounting (banking industry)	Old	Machine-aided hand processing of checks and deposit slips
	New	Electronic data-processing

Annealing steel strip (steel industry)	Old	Batch annealing of coiled strip under portable furnaces
	New	Continuous annealing of endless uncoiled strip through stationary furnaces
Coating steel strip (steel industry)	Old	Hot-dip sheet-galvanizing and tinplating
	New	Continuous strip-galvanizing and electrolytic tinplating
Machining complex aircraft components from castings (aerospace industry)	Old	Manual and semi-automatic machine tool setup and operation
	New	Numerically-controlled machining

Specific data are given on each process in each firm in the main body of the report.

1. The following substantive conclusions were drawn from the main quantitative analysis of per-unit manhour inputs combined with job-evaluation data:
    a. As expected, in each case the introduction of more highly mechanized production methods was associated with substantial reductions in total manhours required per unit product (direct labor). Productivity increases ranged from 26.5% to 271%.

    b. A given process showed closely similar patterns, both of unit labor requirement and of change with technological advance, when operated in different firms and organizations.

    c. Different processes showed statistically significant differences in skill requirement and different patterns of change with technological advance.

    d. The skill-profiles for the older technologies in banking and steel processes showed a preponderance of middle-level skills, while in aerospace machining processes higher levels predominated. It may plausibly be surmised that the absence of lower-level skills is associated with the fact that the older processes were already highly mechanized.

    e. The reduction in per unit labor requirements due to introduction of new processes was concentrated in the middle range of skills, except for aerospace machining where the higher level skills showed most reduction.

f. Mean skill-levels were increased to a statistically significant extent in all cases except aerospace machining (where they were reduced significantly). However the changes recorded were all small both in relative and absolute magnitude.

g. Absolute per unit labor requirements in the top skill groups were reduced in all cases except demand-deposit accounting and galvanizing. Even in these two instances the increases were small in terms of full time job equivalents. Thus the evidence does not support the widely expressed view that advanced production technology substantially raises the requirement for highly-skilled operating personnel.

h. The overall impact of the advanced technologies studied was a small net increase in mean skill level due to a larger reduction in middle-level than in higher-level skills.

2. The results summarized above were confirmed by assessment of educational and job-experience requirements which were found to rise very little with advancing technology. However these changes could not be tested for statistical significance.

3. The diversity of skill-content (as distinct from skill-level) was assessed by a count of job-types, and the results indicate greater diversity in one case only, demand-deposit accounting. Job diversity showed little change in manufacturing industry.

D. Projections of manpower and skill requirements by process

For four processes out of the five studied it proved possible to combine data on projected demand and on the diffusion of new processes with the skill-profiles giving unit labor requirement by skill-level, and thus estimate future trends both in total employment and for employment in the different skill-groupings.

Demand-deposit accounting showed a "plateau" during the mid-sixties, expected to give way to renewed increase in requirement for middle-level skills about 1970. Higher skills showed a stepwise increase in the early sixties and are likely to remain nearly static from now on.

The steel-making processes all showed pronounced flattening of the employment curve, amounting to a stationary labor-force. This is compatible with entry into a "labor-static" phase of technological advance as hypothesized by earlier observers (the meaning and significance of the "labor static" phase are explained fully in the main body of the report).

No projections could be obtained for aerospace machining due to unpredictable demand.

* * *

CHAPTER
1. INTRODUCTION AND STATEMENT OF PROBLEM

Technological Change and Labor Mobility

Technological change and improvement in methods of production, distribution and the conduct of services has continued without interruption for the past century and a half in the industrial economies of America and Western Europe, affecting all industries and services, and virtually the whole population in one way or another. The aggregate result has been a steady growth in per capita production and therefore in per capita income, to the evident advantage of society as a whole. Broadly speaking increases in average productivity are offset by increases in aggregate demand, so that overall unemployment rates have remained stable within the comparatively narrow range of, say, 2-15%, while per capita production has risen many hundred percent.

But since productivity increases in any one sector, industry, or industrial unit are seldom exactly or immediately matched by increases in demand for that particular product, the general growth of production entails displacement of workpeople from some production units while vacancies occur in others. Thus to meet the needs of the production system, members of the labor-force must be able and ready to move from one job to another with relative ease. The extent of this perpetual movement from job to job is partly but not wholly reflected in recorded overall statistics such as labor turnover. Much of the movement takes place within firms and goes externally unreported, a trend increasing with the average size of firms.

At each move a worker must acquire new knowledge and the skills needed to perform his new job, so that technological change and economic growth place substantial demands on the learning capacity and adaptability of individuals. Until recently the needed relearning and relocation processes were allowed to proceed spontaneously on the assumption that the stimulus of economic need experienced at the individual level sufficed to provide all the incentive necessary to maintain the required mobility of the labor-force, a view apparently well justified at least in American society, though no serious attempt seems to have been made to estimate the hardship to individuals or the retarding effect on economic growth caused by ineffective relearning or resistance to relocation.

More recently the federal government has sought to assist the natural workings of the labor market and facilitate adjustment to technological change by the adoption of an active manpower policy. In particular, efforts have been made under the Manpower Development and Training Act to train actually or prospectively unemployed workers for new jobs with different educational and skill requirements, a function previously performed piecemeal by those firms needing extra manpower or by individual workers seeking to better themselves.

Normal job-training programs either privately run or Government-sponsored, aim to impart new knowledge and skills at broadly the same level of difficulty as those exercised in previous jobs but short training courses can only be expected to raise the general level of education or skill of their recruits to a very limited extent. Thus if the new jobs being created by the introduction of newer technologies on average require a substantially higher level of education or skill than those being destroyed, a shortage of well-qualified workers might arise in the labor-market while underqualified ones remained unemployed. Only basic re-education of large masses of workpeople (or waiting for a new, better-educated generation) could resolve this situation which is termed "structural unemployment".

Evidence for increases in mean skill-level required by newer technologies

Many observers (e.g. Drucker (1), Diebold (2)) have suggested that certain current technological developments falling under the general heading of automation do have precisely this effect, since they introduce new and more complicated types of automatic equipment requiring higher skills to operate and maintain, where the work was previously done by semiskilled operatives. Some statistical backing for this view has been adduced by observers such as Charles C. Killingworth (3) who pointed to the generally lower and diminishing labor-force participation-rates of less-educated workers as evidence that they were being squeezed out of the labor-market. However his data can also be explained in terms of age-distribution, since with a steadily extending period of full-time education older workers would both have received less education and be more likely to retire or cease participation either voluntarily, for medical reasons, or under pension schemes, producing exactly the effect he notes.

No other aggregate statistical data seem applicable to testing the hypothesis that current types of technological change cause marked upward shifts in the level of skill required of the labor-force. The rising level of average educational attainment in the labor force is more readily explained by the fact that more highly educated recruits are available than in the past and that, other things being equal, employers prefer better-educated recruits, than that higher skill levels are strictly needed to meet production needs. What evidence can be gleaned from the current downward trend in unemployment rates indeed suggests that given sufficient aggregate demand, less-qualified workers can readily be absorbed by the labor-market.*

A number of direct case-studies have been made of job and skill developments related to specific technological changes (References 4-8), attempting to ascertain what changes in level and/or content of skills have been required, and many observers have reported on individual firms' or plants' experience in introducing new processes or methods such as the automatic operation of special-purpose machines, automatic control of processes, electronic data-processing, numerically controlled machine tools, automatic inspection and so forth. Cases have been reported where old skills have been upgraded (particularly in maintenance and process operation) or downgraded (in operating automatic machines) and where new skills have been introduced (such as computer programming), but it is generally difficult to draw general conclusions from the reports of job gains or losses given in these cases, for one or more of the following reasons:

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*written in March 1966. Experience to September 1966 suggests that there is indeed a structural unemployment problem, since overall unemployment rates have not gone much below 4% though labor shortages exist.

a) the newer process often makes a product significantly different from the older one;
b) it usually produces at greater volume or the same volume at higher quality;
c) technological changes are often accompanied by reorganization, new staffing policies, or different methods of payment;
d) observations are often taken before the new process has been fully commissioned or run-in, and the special skills required for the transient phase of process development are incorrectly ascribed to the basic needs of the process itself;
e) unrecorded division or sharing of workers' time or effort between different processes or activities may falsify results based on total manning figures;
f) component operations within a supposedly automated process often represent very different technological levels, with unmechanized operations using a disproportionate amount of labor, and it is hard to know what the outcome of complete automation would be;
g) inadequate means are often used to assess the skill-levels required to operate or maintain equipment, including reliance on inexpert subjective judgement;
h) the level of productivity and skill-demand may vary with the volume of demand for the product, set by the market.

In order to show that a given technological advance entails a real net increase in required skill-level, it would be necessary, after controlling the factors mentioned above, not only to establish the presence of higher skills in the new operating team, but to ascertain their amount in proportion to other skills required by the newer process and to those displaced from the older one.

Following normal trends, the newer process will usually require less total manpower, and the question is whether whatever new higher-level skills are involved represent a greater proportion of the reduced total manpower, not simply whether they exist. Head-counts of numbers employed on old and new processes - the most frequently collected quantitative data - do not yield satisfactory estimates of the relationship between older and newer methods, unless care is taken to ensure that all the labor of those counted is actually expended on the process in question.

Perhaps the most carefully conducted direct attempt to ascertain the effect of increasing mechanization on skill-demand was made in the middle 1950's by James R. Bright, in connection with his extended field studies of automation and management (9). He reported analytical results from a large number of plants chosen as instances of several distinct types of production technology, but he found that measuring changes in total manpower due to automation was far from easy even for the firm itself (op.cit. Appendix XI). He did not attempt to split up the total figures by skill level and hence assess the proportion of new skills in relation to the new total manpower, since this would presumably require still more finesse.

Bright's general conclusion (op.cit. Chapter 12) was that high levels of mechanization lead to a net reduction in mean skill level rather than the previously predicted increase, after a temporary rise associated with partial or imperfect automatic control. This view, evidently based on a substantial amount of direct observation but not adequately supported by hard data, appears to be the best-founded assessment to date, though it conflicts with a large number of other observers' opinions. It was therefore adopted as an initial hypothesis to be tested by more exact methods in the present study.

The feasibility of obtaining direct data on productivity and per-unit labor requirements has, however, been established beyond doubt by the extensive series of so-called "direct productivity" studies conducted by the Bureau of Labor Statistics in the years 1951-55 (10). Some 45 reports were prepared giving per-unit labor requirements in a number of different processes within various industries. The data were gathered mainly to provide a standard of comparison for use by European industry and no attempts were made to compare different technological levels in a controlled way nor to examine skill-levels. Nevertheless the method provides a valuable point of departure for the present study.

Bright also drew attention to the spread of skill-levels and variation in job-content characteristic of most industrial processes, and these characteristics may also be found to change with advancing mechanization and automation. This question was discussed in a recent theoretical paper by Sultan and Prasow who suggested as an extreme example that skill-levels may ultimately take up a bimodal distribution, with fewer demands in the middle range than at either end of the scale. This would happen if both the very highly skilled and the unskilled categories increased with automation(11). There are indications in some of the previously reported studies that this possibility may be a real one.

In summary, it is much easier to cite opinions than adduce evidence for the supposed upgrading or downgrading of skills due to advanced mechanization and automation; what evidence there is indicates no great change in mean level but perhaps an increase in spread. The main objective of the present project has been to acquire further valid data to decide which of the various views come nearest to the truth.

Generalization over technologies

We have hitherto argued as if changes in skill-demand caused by the introduction of new, automated, technologies proceed uniformly over all industries and services, an unlikely event given the great variety of demands made by different processes. Descriptions given by Crossman, for example, indicate that requirements may differ very markedly within a single advanced industry such as iron and steel (7), and a study of job-descriptions published by Louis Levine (12) indicates that a very wide variety of activities are involved in modern production systems.

Clearly the results of isolated case-studies cannot immediately be generalized even over the rest of the same industry, still less over the economy as a whole. However, the difficulty here seems to be more apparent than real, and is at least partly due to the conventional scheme of classification which groups production systems into industries and services by the product manufactured or the service provided. Naturally each product requires different raw materials and a different sequence of manufacturing operations. But looked at from the standpoint of the processes employed, and disregarding the specifics which make up the content of an operator's knowledge and skill, there are relatively few basic types of process. Each industry uses a different combination of a few fundamentally similar operations, geared to its own particular needs.

Thus it seems that the proper approach would be to seek results capable of generalization over a single type of production technology, rather than a single industry. For instance the continuous processing of strip materials has similar requirements in the steel industry, paper and board-making, textiles, and plastics and it would be reasonable to expect similar changes in skill-demand to occur in each as automation proceeds; likewise computerized data-processing for demand deposit accounting, insurance, payroll accounting, invoicing; and so forth.

A fully satisfactory classification of production technologies (as distinct from industries) has not yet been established, though the recent report prepared for O.M.A.T. by A.D. Little, Inc. on "Evaluation of Automation Potential by Unit Operations" provides valuable guidelines at a somewhat more detailed level (13). Since skill-demands are essentially the requirements of a process for information and control inputs by the human operator, a good prospect exists for classifying processes according to their informational needs as outlined by Crossman in recent theoretical papers (14,15). Though neither of these taxonomic principles have been fully exploited as yet, the general background they provide suggests that a modest number of studies on carefully selected processes representative of each distinct type of production technology would enable valid inferences to be drawn covering a substantial part of the economy. It is not necessary to examine every skill process in every industry, an impossibly large task.

Manpower and skill predictions for particular industries and services

Apart from the general desirability of deciding the question whether automation and advanced mechanization tend to raise or lower skill-requirements in the economy as a whole, it is perhaps more immediately important for an active manpower policy to develop a method of forecasting the skill and manpower impact of specific technological advances known to be under way in particular industries. For instance, what will be the net effect of the current computerization of federal government clerical operations? If the likely manpower changes were known sufficiently far in advance it would be possible to set up job-training, retraining and relocation programs closely matched to the future demands of the situation.

The problem here is a limited local version of the broader one stated above, and implies the same set of requirements for valid data-collection and inference. However with a more limited population of processes it is possible to envisage more precise prediction based jointly on (a) the per-unit skill impact of the new technology, (b) the projected total demand for the product or service, and (c) the rate of diffusion, i.e., the rate at which the new technology replaces the old. From a knowledge of these three factors it should be possible to predict the skilled manpower needs of a given technology quite accurately for several years ahead. At the present time these projections appear to be obtained by aggregating the manpower forecasts of individual firms, a method which is inaccurate to the extent that firms usually do not have the data to determine the outcome of a projected development until after the event and it is also subject to an unknown amount of bias in the direction which a firm considers to be the desirable outcome for reporting to a government agency.

A secondary objective of the present study has therefore been to develop an instrument capable of giving unbiased projections of the manpower impact of specific advances in production technology, taking future demand into account and using sample studies of industry leaders to provide information capable of extrapolation to the industry as a whole.

§§ CHAPTER

2. OBJECTIVES AND METHODOLOGY

The remainder of the report describes the methods and results of a pilot investigation of the impact of changing technology on jobs and skills, initiated in the hope of shedding further light on the problems outlined above. Four selected changes in process-technology have been examined, two in the steel industry, one in the aerospace industry and one in a service (banking).

Specific objectives

The initial objectives, as set out in the research proposal submitted to O.M.A.T., were "to develop suitable analytic methodology for the identification of skill changes and to utilize the methodology to provide an up-to-date account of job and skill trends within operating groups associated with machine and plant operation". In particular it was desired to test the hypothesis derived from the earlier results of J.R. Bright and others, that the highest levels of mechanization and automation require on average *lower* levels of skill in the workforce, than do earlier production systems. Observations were to be extended to further industries and services, and conducted by more exact methods than previous researchers had been able to adopt. If possible it was hoped to collect data permitting statistically valid inference covering reasonably wide sectors of industry.

Conditions for data-collection

On the basis of initial discussions, surveys of the relevant literature, and site visits to industrial plants in the San Francisco Bay area, it was decided that a new more quantitative methodology would be required. It seemed that the various difficulties which arise in attempting to compare the skill requirements of old and new technologies by collection and analysis of data on manpower and skills (see Chapter 1) could be overcome by meeting the following conditions in conducting studies of carefully selected cases:

1) comparisons should be drawn between pairs of processes being operated in the same firm at markedly different technological levels;
2) the newer of the two technologies should be representative of the most advanced commercially viable practice in the industry concerned;
3) the processes being compared should start with the same or closely comparable inputs (raw materials, partly worked materials or input data);
4) they should produce the same or closely comparable outputs (products, processed materials to the same quality specifications or output data);
5) the data recorded and compared for research purposes (either numbers employed or manhours) should reflect only manpower or labor time actually consumed in the production process itself, as distinguished from that devoted to in-plant or product development;
6) assessment of skill-levels and analysis of skill contents should be conducted on the same basis for both members of a pair preferably by reference to standards independent of the research teams' subjective judgement;
7) the processes studied should be operating in a steady state at the time of observation to avoid bias from transient effects due to the increased manning and skill which is normally required while commissioning or "debugging" a new plant or system;
8) comparisons should be referred to the same relative level of demand for the product, usually 100% of plant capacity.

Statistical control

If this formidable list of requirements can be satisfied the results emerge as matched pairs of skill-profiles (or other related quantities) permitting statistically controlled comparisons between technological levels in otherwise identical processes. The difference between a single matched pair measures the manpower effects of the given technological change, and if the results can be extrapolated to other similar processes, it becomes possible to predict the total effect of that change on the labor force required by the industry or service in which it is located, and hence on the industry's total demand for specific skills and skill-levels.

However a single pair of readings does not enable one to estimate the reliability of the original data nor permit plausible projections to be derived from them; for this it is further necessary to define the population over which one wishes to generalize and sample it by selecting at least two members at random to obtain an estimate of the error variance of the data. This provides a measure of the overall error of observation and establishes the level of confidence at which inferences can be drawn from the sample results to the population as a whole. This is a straightforward application of the principles of statistical inference, and standard methods such as the analysis of variance (16) are available for interpreting the quantitative results obtained.

In our case the population in question is the set of all technologically similar processes operating in the geographical area concerned, for instance paper-mills in the United States or in California. Within this set the main sources of variability are probably differences in efficiency and "style" between the various firms and organizations operating the processes, and of individual plants within firms. It was therefore deemed appropriate to replicate each matched pair of observations in at least two firms or organizations. One should ideally also replicate within each firm, but this did not prove possible and the results given below are based on matched pairs of processes drawn from each of two or more firms.

Choice of cases

The principal difficulty met with in seeking material to satisfy the criteria listed above was that few firms can be found operating processes at two different technological levels producing a closely similar product. Almost invariably an older and less productive process is dropped as soon as a newer one is well established, and if not, it operates on a much reduced scale, perhaps for a special range of products only. This considerably limits the choice of case-material, but enough satisfactory instances were found to satisfy the data-collection scheme outlined above in four distinct types of process, which were all that time would in any case have permitted. In future studies it may be possible to use records referring to obsolete processes, which would considerably extend the range of choice. But this expedient was not considered satisfactory for a pilot study involving new methodology.

Choice of a dependent variable to measure manpower requirement

In previous inter-technology comparisons of manpower and skill the major dependent variable usually was number of men employed on a plant process, or labor-cost which is presumed to be highly correlated with manpower requirement. The first of these measures is usually contaminated by changes in the amount of peripheral and "overhead" activity associated with, but not caused by, the technological change itself; also it is not sufficiently discriminating, since a single worker's time is very frequently divided or shared between several different processes or products. This is particularly true of more highly mechanized plants where the labor requirement of any given operation is low. Cost data may be more discriminating but firms are normally reluctant to divulge it for reasons of commercial security; and where supplied, it is not direct data, but has usually been derived by management from time-standards and other primary measurements with ad hoc corrections made for purposes such as incentive payment that are irrelevant to manpower research.

It was therefore decided to work with the primary data itself viz man-hour requirements per unit product, derived from industrial-engineering time-standards or other time-measurements which can be readily verified by direct observation. In the upshot this proved to be a satisfactory choice and complete data were readily collected for all the processes chosen. Where the original data was supplied by the firm it was checked in a sufficient number of cases to ensure reliability.

Assessment of skill-levels and job-contents

A second dependent variable, ski~~ll-~~level, must be measured in order to construct skill-profiles, and this presented more difficulties.

Several alternative bases of measurement were considered, including length and type of education; amount and type of special training; a factor-point scheme by which the team's observers could assess job and task-difficulty according to the amount of memory, decision or direct data-processing required; manhours expended in training; and various less conventional approaches. But none of them were judged both to relate sufficiently closely to the tasks actually being performed in the production process and to be sufficiently free of subjectivism to yield statistically sound results.

The choice therefore fell on using factor point scores from the firm's own job-evaluation schemes. All the firms approached were found to be using some form of job evaluation or grading based on assessments of difficulty made in carefully conducted reviews and updated from time to time. Though derived from subjective judgement these schemes are analytical in the sense that the final score is reached by combining points allocated separately by individual analysts under a number of separate headings such as job-knowledge, responsibility, stress, working conditions and so forth. Scores are reviewed by more than one person representing different professional interests and areas of knowledge within the firm process. Results are subject to challenge by interested parties and this ensures careful consideration. Thus it was felt that this data embodies more direct and more analytical assessments of the actual needs of the job than the team itself could hope to achieve in reasonable time. The specific manner of developing a skill-scale from job-evaluation data is described below.

While it was decided to use point-scores derived from job-evaluation for the skill-profiles proper, the various other possible criteria of skill-level noted above were not neglected, and complete job-descriptions, estimates of education and training requirements, and on-the-job experience were also collected and tabulated.

Process technology and level of mechanization

As many previous observers have noted, the concepts of "automation", "mechanization", and "technological advance" are hard to define adequately and still harder to quantify when applied to the actual details of processes operating on the shop floor. It is usually the case that -

1) a total process comprises several distinct operations, each with a different type of machine or plant;
2) power is supplied to, and control exercised over, each of the separate operations in many different ways, usually involving an intricate pattern of functioning in space and time;
3) the amount and type of control required varies widely according to the material being processed and various other factors such as the range of product variation required for the market;
4) the division of control between manual and automatic methods varies through time, for instance where a machine-tool operates automatically for part of the work-cycle, and under manual control for the rest.

These and other wide qualitative differences between operations mean that even a single operation cannot be strictly compared with another and placed on a one-dimensional scale of "level of mechanization" or "degree of automation"; portions of complete processes usually defy exact categorization. Nevertheless it is possible at a subjective level to assess what previous observers have called "degree of automaticity" as a global quality of particular processes, and to rank different methods of making the same product on this basis, which may be interpreted as relative level of automation.

An extended treatment of the problem of classifying and measuring the technological characteristics of processes will not be given here. It is felt that the relative technological levels that have been ascribed to the pairs of processes chosen are not likely to be disputed, and it was not an objective of the study to develop further methodology in this direction. However since further analysis of the material may be feasible in the light of later developments and concepts used by other researchers, fairly complete technological details of the processes studied were collected and are reported here.

As a preliminary attempt to relate the present findings to those of other studies, the component operations from which manhour and skill-level data were collected were ranked by level of mechanization on the 17-point scale developed and used by Bright (see Appendices I,II,III). In nearly all cases it was difficult to decide on the correct assignment of level 3 (powered hand tools), and the figures given should be treated with some reserve. In several cases the scale value derived from the application of Bright's criteria seems to misrepresent the subjectively assessed "degree of automaticity" rather seriously. Ideally a more discriminating scale should be developed with at least three and probably more dimensions, i.e., level of power-actuation, level of automaticity in determining the sequence of actions executed, and level of automaticity in regulating process variables. Nevertheless the Bright-scale values do give an idea of the relative levels of mechanization involved.

Economic aspects of the processes studied

It was initially hoped to study some of the economic results produced by technological changes in productivity and skill-requirement, but it did not prove possible to acquire and report sufficient data from the firms studied to permit useful conclusions on such questions as relative cost, profitability and so forth. It was also hoped to investigate the economic and other reasons for the decision to change from one process to another in the firms concerned, but this again did not prove feasible.

§§ CHAPTER

3. CONDUCT OF FIELD STUDIES

Initial Exploration

At the start of the project a number of site visits were paid to firms in the San Francisco Bay area and elsewhere in California to identify currently significant changes in process technology, and to explore the possibilities of identifying skill-changes. The range of choice was found to be significantly restricted by the relative lack of heavy industry and of such major industries as automobile manufacturing and heavy chemicals in the area, but several more or less suitable types of technological change in major industries were examined as possibilities for detailed study.

During this period it was decided to attempt the more thoroughgoing quantitative approach to manpower and skill problems outlined in Chapter 2 rather than the looser procedures that have hitherto been used in field case studies. The new approach would take direct productivity measurements similar to those reported in studies by the Bureau of Labor Statistics in the years 1948-55, and further provide a breakdown of manhour requirements by skill-levels.

On more detailed analysis of the measurement problems involved it became clear that more stringent criteria would be required in the selection of case-material than had been initially envisaged if a satisfactory level of statistical control and reliability of evidence was to be attained, and the file of possible cases was reviewed with the criteria set out in Chapter 2 above in mind. For the first detailed study to be undertaken a process involving manipulation of numerical data rather than physical processing of materials was preferred, as it was felt that here problems of product specification would be more readily soluble. Some form of digital data-processing conducted in large volume seemed the most likely to provide a tractable yet meaningful pilot study, a view which was reinforced by the appearance of a recent study by the Bureau of Labor Statistics‡ on E.D.P. in the insurance industry.

Selection of specific cases for study

1. Banking

Among the various services using E.D.P. that were initially reviewed, the process of check-clearance and account posting in banks most nearly met the criteria and permission was secured to conduct pilot trials of the new methodology in Firm A, a large bank operating in the San Francisco Bay area. The firm had recently accomplished a major technological advance in its demand-deposit accounting operations, changing over from machine-aided check-processing and account-posting conducted independently at local branches, to centralized check-processing and computer-based account-posting with records held on magnetic tape rather than printed file-cards. (Detailed accounts of the old and new processes are given in Chapter 4 and Appendix I). A few branches of this bank were found to be still using the older method and this permitted controlled comparisons to be drawn between the older and newer systems.

When the study in Firm A was nearly complete,a search was instituted for a second comparable case, and another large bank (Firm B) agreed to cooperate. The newer method of check-processing here was somewhat more advanced than that in Firm A, though based on very similar concepts. Firm B's system was found to be more centralized, further functions such as check-filing originally performed at the branches having been transferred to regional centers. In other respects the two sets of data collected were based on closely comparable situations and,being jointly representative of modern check-processing systems in general, were judged to permit extrapolation to the total population of demand-deposit accounting systems based on electronic computers (see Chapter 6 and Appendix I).

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‡ "Impact of Office Automation in the Insurance Industry", Washington, U.S. Department of Labor, Bureau of Labor Statistics, Bulletin 1468, December 1965.

2. Steel

When the first set of studies, in banking, had begun to yield results it was decided to study the changeover from batchwise to continuous processing in a heavy industry as another technological change having wide significance. Possibilities existed in chemical, paper and glass-making firms, but steel seemed the most promising because of the rather clear and distinctive technological advances that had been achieved in recent years. Inquiries conducted while the banking study was in progress led to an offer by a large local steelworks to explore the possibility of singling out one or more processes which might be amenable to the approach adopted. Since this steelworks was not engaged in basic steelmaking processes, the choice was restricted to finishing processes, being applied to materials shipped from the company's other plants. Heat treatment of coiled strip and the subsequent coating processes were finally chosen as in both cases technologically advanced new plant had been installed since the war, while the older processes had not been entirely discontinued. In the case of annealing (heat treatment), the older batch method actually turned out a type of product still in great demand which could not be manufactured by the newer continuous method.

Further exploration brought the project team up against a difficulty which may impose significant restrictions on the use of the methodology for the comparative evaluation of other manufacturing processes where a newer technology is replacing the older. This difficulty lies in the fact that radical modificationsin processing equipment are often incidental to(or consequent on) equally radical changes in the specification of the product manufactured[‡]. Where this is the case it may not be valid to compare the skill inputs for a product manufactured by one technology with those for another technology, since the products differ. In this case batch annealing and continuous annealing were found to produce a different range of steels. But there was some overlap and a product common to both processes was selected for a comparison of manhour/skill inputs. Much the same state of affairs existed in galvanizing where only one product qualified for comparison. Moreover it was discovered that the older galvanizing process had been almost completely displaced throughout the U.S.A. and the works where the inquiries were conducted was the last in California where it still survived. Thus the galvanizing study could not be replicated in another firm. It was therefore decided that tinplating, a process which has many points in common with galvanizing in both its older and newer versions, would be considered as an alternative. Again the older technology had survived in only one steelworks, which happened to be elsewhere in California.

When this second steelfirm was approached and agreed to cooperate, the way was open for a direct replication of the annealing study and for near-replication of the galvanizing study in one firm by an investigation of tinplating in the other, industry experts having assured us that the manhour inputs and skill demands of the two processes were closely comparable. Difficulty in finding identical products manufactured by the older and newer technologies also arose in tinplating and was overcome by similar means, as noted in more detail below.

[‡] Diebold (2) urged many years ago that the re-thinking of products should precede or go hand in hand with the re-design of equipment, insisting that the substantial productivity gains inherent in automation could only be realized if no aspects of existing technology were looked upon as immutable constants.

3. Metal-working

For the third area of study it was decided to select a process representative of the metal-working industries since these are in many ways a central type of industrial activity accounting for a significant fraction of the total workforce. Transfer machining would have provided a useful study, but no suitable plant could be found in California. Instead the choice fell on numerical control of machine-tools, which bulks large in the aerospace industries of the West Coast and was therefore accessible for study; another important consideration was the availability of a recent survey of the field conducted and published by the Bureau of Labor Statistics[‡] which had reviewed much of the relevent background.

For these studies advice and support was sought from the International Association of Machinists and Aerospace Workers, who suggested two aerospace firms in Southern California as probably suitable for the type of study envisioned in the project objectives. Of these one proved suitable and this firm's personnel, like that of another aerospace firm approached later for purposes of replication, went to considerable trouble to find complex components which were previously machined conventionally and had later been assigned for whole or partial machining on numerically controlled tools. As some of the components were not actually in production at the time of the study, the personnel in both aerospace firms were called upon to give much more of their time and effort to locating documents in files, examining whether transfer to n/c machining was not accompanied with a change in the design of the component, etc. than was the case in other studies.

Summary of case-material finally selected

The processes finally selected may be summarized as follows; data were collected independently from two separate firms in each case.

1. Banking

		Study
Check Transactions	Customers' checks or deposits cleared and accounts posted.	
Technological Level 1	Hand-operated accounting machines with hand-sorting and records kept on ledger cards.	A1, B1
Technological Level 2	Electronic Data Processing systems with manual data input and records kept on magnetic tape.	A2, B2

[‡] "Outlook for Numerical Control of Machine Tools", Washington, U.S. Department of Labor, Bureau of Labor Statistics; March 1965, Bulletin No. 1437.

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2. Steel industry

		Study
Annealing Steel Strip -	Heat treatment of steel strip intended to normalize structure after cold-rolling; coils of given size.	
Technological Level 1 -	Box process - coils electrolytically cleaned, then stacked on bases, portable furnaces lowered over them, gas-heated on a prearranged time-temperature cycle and unloaded.	C1, D1
Technological Level 2 -	Continuous annealing - coils loaded, welded end to end, passed continuously through electrolytic cleaning tanks, through a furnace under automatic control, and recoiled.	C2, D2
Coating steel strip -	Strip of given width and gauge supplied in coil form, being tinned or galvanized, and cut into sheets of desired length.	
Technological Level 1 -	Hot-dip processes - coil sheared into sheets, transported in stacks to the coating line, dipped in a hot metal (zinc or tin) bath, cooled, inspected and stacked.	C3, D3
Technological Level 2 -	Continuous galvanizing and electrolytic tinplating - coils welded continuously, running strip cleaned, prepared, coated and recoiled or sheared.	C4, D4

3. Metal-working industry

Machining aerospace components -	Castings in aluminum or mild steel being milled, drilled or turned to specified dimensions with close tolerances and complex shapes.	
Technological Level 1 -	Conventional machining - (special jigs, fixtures, and cutting tools supplied for each part). Castings loaded into a fixture, tool inserted, machined according to preplanned sequence of operations, unloaded and handfinished in a tumbler or with hand tools.	E1, F1
Technological Level 2 -	Numerical control - As above, the cutting operations being controlled by punched tape or other digital method.	E2, F2

Detailed accounts of all the processes studied and comparative tables of product specifications are included in the Appendices each of which deals with a set of studies related to one product. The brief descriptions given in Chapter 4 below are mainly intended to convey some idea of the differences between the older and newer technologies employed for each product.

4. Collection of Data

All information included in this report refers to direct labor, defined as:

> personnel engaged on jobs or tasks making a direct contribution to the conversion of material inputs into products or to the execution of services ordered by customers.

Accordingly the study did not extend to

> personnel wholly employed in maintaining, servicing or repairing the tools or machines used by direct labor to effect conversions on material inputs into products or required for the processing of data linked to the execution of services;
>
> supervisory personnel forming part of the line function;
>
> managerial, staff, engineering or research personnel constituting the organizational, coordinating and supportive function;
>
> purchasing, sales and accounting personnel.

Towards the objectives outlined, it was decided to collect:

(i) information on the whole range of input materials undergoing conversion in each process studied;

(ii) information on the products out of this range for which details were to be sought on the direct labor contributions at two technological levels;

(iii) technical information on the processes and procedures used to effect the required conversions of the specified materials or items;

(iv) the job titles of all operators engaged in each process at both technological levels and the corresponding job descriptions, their Dictionary of Occupational Titles codes, their general educational background and the length of on the job experience and/or special training required to reach acceptable standards of performance;

(v) the job evaluation or rating schemes used by each firm for grading their personnel, and the skill ratings allocated to each job considered;

(vi) the number of manhours contributed by each operator in the course of processing a given volume of the specified product or service;

(vii) background data on the industries concerned, their product mix, manpower situation and possible or probable future developments in production technology.

These seven sets of data were collected for two technological levels of each of four processes to be examined, at two firms each, yielding a total of sixteen distinct studies. Furthermore, in one instance (banking, Firm A) by good fortune we were able to obtain records for a comparison of the total operations of the bank before and after the introduction of the major technological innovation studied; this data is reported as Studies A3, A4.

Methods adopted for measuring skill level

Devising a skill-scale runs up against the many difficult problems inherent in measuring skill. A number of methods of varying degrees of sophistication were proposed and tested in trial runs; some of these are being developed further. It soon became clear, however, that if complex methods were used to estimate skill level, with all the other complications invariably attending field studies in industry, the research might yield little in terms of tangible results in the one year allowed for the pilot study. For this reason it was decided to base the skill scale used for developing skill-distributions on skill ratings derived from the job evaluation schemes which are used in one form or another by most firms in the manufacturing and service industries. While it was realized that this procedure is open to objections from a skill-theoretic point of view since it does not provide an absolute standard of reference,the team felt that, apart from the relative ease of obtaining relevant data, it also had the highly desirable advantage of pragmatic acceptability and ready comprehensibility by the companies whose help was enlisted.

One kind of job evaluation scheme used in industry is based on job descriptions together with a listing of attributes considered necessary for success in the job and difficulties involved in its performance, arranged under a series of headings; each of these headings or "factors" carries a certain weight, and the job analyst assigns points out of a corresponding maximum for each factor on each job evaluated. The sum total of points is an overall index of the "demands" of the job. The factors usually cover the following ground - 1) the amount of native ability, education, special training and/or experience needed for an acceptable performance of the job; 2) the degree of responsibility attached to the job; 3) the physical or mental "effort" involved; and 4) special discomforts or hazards inherent in the working environment where the job is performed. For example, the scheme in use throughout the steel industry is based on the following breakdown;-

Training and skill	(Pre-employment training
	(Employment-training and experience
	(Mental skill
	(Manual skill
Responsibility	(Responsibility for material
	(Responsibility for tools and equipment
	(Responsibility for operations
	(Responsibility for safety of others
Effort	(Mental Effort
	(Physical Effort
Working conditions	(Surroundings
	(Hazards

In most cases, including the steel-industry scheme, job-evaluation scores are very carefully considered, and changes in job descriptions and/or changes in the weights or points allocated under any of the factors are open to negotiation between management and unions. Thus making changes in an established job evaluation scheme tends to be a lengthy and difficult process.

To be of use to the firm, a scheme of this kind, which directly determines pay-rates and differentials for the job, must be maintained at a high level of internal consistency and is therefore a reliable research tool. The growth of new technologies and concomitant creation of new jobs and job-types may raise difficulties for existing schemes. As a general rule companies do not respond by setting up new schemes or adding new factors to cater for newer technologies, since this would lead to inequities and disputes, but new jobs are accommodated within the framework of existing schemes and point-values (factor scores) are assigned using the older jobs as standards. Therefore they have proved of great value for the present purpose which requires exactly this type of standardization.

Since the present project is specifically concerned with changes in skill occasioned by advancing technology, only those job-evalution factors judged to relate directly to skill, training or education were taken into account in constructing scales for use in the research. Detailed procedures will be discussed further below but at this stage two disadvantages of using company job evaluation schemes should be pointed out. First, as will be seen, they make it difficult to draw comparisons between processes in different industries or firms which usually have distinctly different schemes; Second they allow the construction of ordinal but not ratio scales; consequently statistics such as "mean skill level" must be treated with caution, since a zero point-score does not necessarily imply zero skill.

Selection of products for controlled comparisons between old and new processes

Identity of inputs and outputs of a given process operated at two or more technological levels has already been mentioned as a major control needed in establishing comparability. Its application also severely limited the choice of cases, especially in the manufacturing industries. Out of a variety of similar products being made at two different technological levels, there were usually only very few identical both as to input (raw material used) and output (dimensions and quality specification of the product).

There was thus little elbowroom left for satisfying the further criterion, that the product/process combination should in both cases be typical or normal with respect to the whole product mix. While it is felt that in the outcome all the products selected are reasonably typical of the mixes from which they have been drawn, fairly full data are given on the composition of these mixes to enable the reader to form his own impressions in this respect. These data are given in appendices relating to all the processes studied except that for banking (Studies A1,2,3,4,; B1,2); in the latter case,checks and deposit slips are sufficiently standard to leave no doubt of their representativeness. Other banking processes, e.g., those for loans and savings account transactions, are quite distinct from demand-deposit accounting and no confusion arose.

Tables given in the appendices list the main parameters of variation between products in the mixes. The full range of variation over all products is given and is followed by the (narrower) range for the most "frequent" product or process. Finally the specifications for the product used in this study are given in the last row. Examination of these tables (Appendix II, Tables II - 1,2,3,4) shows that in the two studies of annealing (Cases C3, C4, D3, D4), the products selected fell within the ranges of the most frequently produced component for all the relevant dimensions in both the newer and older technologies.

In galvanizing (Cases C1, C2) (Appendix III, Tables III-1,2) matters were complicated by the fact that thin-gauge sheets ceased to be manufactured on the hot-dip line when continuous galvanizing was introduced; the thinnest sheet being processed at the time of study was 14 gauge. On the continuous line the reverse obtained, and gauge 14 was nearly the heaviest that this particular equipment could deal with. Some of the newer continuous lines can produce the heavier gauges demanded by customers and because of this have now almost totally displaced the hot-dip process. However, on both lines gauge 14 constituted only a small proportion of the total throughput and cannot therefore be regarded as fully typical.

Since gauge is the prime determinant of the speed at which the lines can be run, the line speed for the products selected also fell outside the range for the most common products: the hot-dip line was running at nearly its maximum speed, while the continuous line was near its minimum speed when gauge 14 sheets or strip were being coated.

On the tinning process (Cases D1, D2; Appendix III, Tables III-3,4) even the lightest existing coating weights applied by the hot-dip method were heavier than the heaviest coating weights that could be applied on the continuous line. All that could be done was to narrow the gap, by taking processing data for products coated with a 1.10 lb. per base box[*] layer of tin on the hot-dip line, and data for products coated with a 1.00 lb. per base box layer on the continuous line. But while the former of these coating weights was fairly typical of the product mix on the hot-dip line, the latter weight was used for only a very small fraction of the continuous line throughput. The line speed on this line for the product selected was atypically slow, due to the heaviness of the coating.

For the studies of parts machining (Cases E1, E2, F1, F2) it was initially intended to select components which had been wholly machined on conventional machine tools, then transferred to tracer-tools and finally machined entirely on numerically controlled tools.

This design had to be revised when it was found that, though there are still many parts which were machined on conventional tools, no parts were machined entirely either on tracer or n/c tools. Tracer machining appears always to have replaced only a very small fraction of conventional work. It was therefore decided to treat partly tracer-machined parts as conventionally machined parts and to confine the study to comparisons between the manhour/skill inputs for conventionally produced parts and the corresponding inputs for identical parts where n/c machining had replaced conventional machining to an appreciable extent. The criterion set up was that the amount of cycle time replaced must be at least 66%. The strict application of this criterion involved discarding data for one of the components originally selected (see Appendix IV, Table IV-1).

The determination of the extent to which the parts selected for the comparison between conventional and n/c machining were representative of all parts produced, required some specification of what might be considered the critical dimensions. It was reasoned that the total manhour inputs must be a function of the complexity of a part and to some extent also of the material used, as aluminum, for example, can be worked very much faster than steel. The level of skill required is clearly related to the complexity of the operations to be carried out on the work piece. Tables IV-3,4,5,6 in Appendix IV contrast the types of metal used and the estimated complexities of all parts produced by either firm on conventional and n/c machine tools with the corresponding properties of the sets of parts for which manhour and skill data were collected; these sets appeared to be reasonably representative of the total range of parts manufactured.

Comparison of the percentages of parts produced with the estimates of complexity supplied by the firms shows a broad correlation, the parts rated more complex tending to be more frequently produced by numerical-control machining. However the difference was small and n/c machining could therefore be regarded as a nearly direct substitution of one process for another, using the same raw material and providing the same class of product.

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[*] The Base Box is a unit of area equal to 217.78 square feet. Tinned products are sold on a weight-of-coating per base box basis rather than a gauge thickness basis.

Process analysis and description

Before a process was finally selected for study, its technological and operational aspects, as well as the standard practices developed for operating it at each level of technology were examined in considerable detail.

The main reason for this was that though the endpoint was established by the final product, it was still necessary to locate the proper starting-point to ensure that the inputs were also the same. For example, as electrolytic cleaning was performed within the sequence of operations in the newer process of continuous annealing (C2,D2), to secure comparability the investigation of the older process of batch or box annealing (C1,D1) had to be extended upstream to include electrolytic cleaning which is done before heat treatment. Similar considerations applied to the coating processes (C3,C4, D3,D4).

In addition, some degree of familiarity with the technological aspects of the processes was needed to interrogate the firms' personnel on the availability of relevant data in the firms' records, to find this data and transform it for the purposes of the inquiry. Information on volume of product and manhours required was in many cases found in different departments from those dealing with job descriptions and job evaluations and this often resulted in substantial discrepancies which had to be corrected through knowing the process itself.

Without good insight into the processes it would also have been difficult to distinguish direct from indirect labor. Extensive and detailed reference was made to work-crew schedules to determine the extent to which operators were actually involved in the processing of the specified product. Some operators, particularly tractor and crane-drivers, were found to be partly or mainly concerned with other product lines and their manhour inputs had to be correspondingly reduced and adjusted. In some cases also the size of the work crew and its manhour contribution depended on the current volume of production, further operators being assigned to the process when the volume exceeded a certain limit. To resolve problems of this kind the advice of work personnel had again to be sought in extended discussion of processes and procedures.

Compiling lists of operators was relatively straight-forward in the bank studies, due to the fact that other banking transactions, such as loans, special credit plans, etc. are dealt with by systems functionally separate from demand-deposit operations. In the steel processes, where varied product mixes are manufactured on the same lines, and where some of the personnel is shared between departments, matters were more complicated. Materials-handling operators, such as crane drivers, tractor drivers, etc., and on-line inspectors, for example, though formally allocated to a single department, actually distribute their working time between several.

Apart from figures on manhours, production volumes were required by reference to which manhour inputs could be prorated per unit product. In some cases immediately usable data were available in the form of total volumes per month or other period; in other cases volumes could be calculated from processing speeds or from records showing standard times for producing a given product or a given volume of product.

Assigning skill-level figures to jobs

The attachment of skill "scores" or points to each job presented little difficulty in the case of the steel industry processes owing to the uniformity in the format of job descriptions and in the job evaluation practices. In the studies of machining, though the evaluation methods in the two aerospace firms were found to be very different, the similiarity in the job titles and job descriptions enabled us to perform a simple conversion of the skill ratings from one firm to those of the other. A member of the staff of the Personnel Relations department of one of the banks cooperated in devising a similar method of conversion between the two banking systems, which were operated on different organizational principles and had a quite different job structure. At the investigators' request he agreed to supply independent skill ratings based on his own bank's scheme for a selected number of jobs in the other. The two skill ratings for each job were plotted on semi-log graph paper and a least-squares regression line was fitted to the data. This enabled the skill scores of all jobs in the second bank to be transformed into those of the first (Appendix I, Figure I-1).

The next step consisted in grouping the jobs at various skill-levels for each pair of technologies into five to seven broader skill-level categories. A computer program was written to calculate the total manhours per unit product for the processes at each technological level, break them down by skill level, express them as percentages of the total per-unit manhour requirement, and calculate the differences between technological levels in the per-unit manhour requirement at each skill level. It also computed the mean skill levels, variances and standard deviations for both technology levels of each process. The manhour inputs at successive skill-levels were finally plotted in the form of histograms or profiles.

As each study was replicated on an identical or near identical process in a second firm it was possible to estimate the variation in the data due to differences between firms, and in the case of machining, to the differences between parts. The statistical technique known as Analysis of Variance was used for this purpose, permitting evaluation of the statistical significance* of the shifts in the skill level associated with changes in technology. The precise form of analysis used was chosen on the advice of a competent statistician.

Education and training data

Throughout the project attempts were made to obtain data on general education and training for each job recorded. But while the records available to us usually contained fairly detailed specifications of the amount of job experience considered necessary for its acceptable performance both in the older and newer technologies, data on the basic educational requirements was difficult to obtain .

The detailed analyses of jobs and tasks that were conducted to further the main objectives of the project did, however, give sufficient insight for the researchers to arrive independently at reasonably plausible estimates of the minimum educational requirements of each job. From these estimates and from the firms' own estimates of the requisite on-the-job experience, it was possible to build up a tentative picture of the changes in educational and experience requirements connected with the observed stages in skill level as between technologies. In every case the data from each pair of firms where the processes had been studied were merged and analyzed jointly when considering educational and experience levels.

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*i.e. the smallness of the probability that the observed differences between technological levels could have been due to chance.

§§ CHAPTER

4. RESULTS AND DISCUSSION

Order of presentation

As indicated above, three of the four processes chosen were studied at two technological levels in each of two different firms: check processing and account posting in two banks, annealing in two steelworks, machining of complex parts in two aerospace firms. For coating steel sheet the older galvanizing and tinplating processes were each extant in only a single steelworks on the West Coast. However these two processes have much in common and the steelworks' industrial engineering personnel judged them to be comparable in point of manpower and skill requirements, so they were treated as equivalent. All the processes examined had been running for more than two years at the time of study.

The results from the sixteen cases are presented and analyzed in subsequent sections with all of the information relating to a given process kept together. Table 1 shows the order of presentation and the code numbers used to identify each firm, process and level of technology.

TABLE 1

TABLE 1

SUMMARY OF CASES STUDIED

Code	Firm	Process	Technology
A1	Bank 1	Check processing and account posting	Machine-aided hand operations
A2	"	"	Computerized
B1	Bank 2	"	Machine aided hand operations
B2	"	"	Computerized
C1	Steelworks 1	Annealing	Batch (or box)
C2	"	"	Continuous
D1	Steelworks 2	"	Batch (or box)
D2	"	"	Continuous
C3	Steelworks 1	Galvanizing	Hot-dip, sheet
C4	"	"	Continuous strip
D3	Steelworks 2	Tinning	Hot-dip, sheet
D4	"	"	Continuous strip
E1	Aerospace firm 1	Machining complex parts	Using conventional machine tools
E2	"	"	More than 2/3 numerically controlled
F1	Aerospace firm 2	"	Using conventional machine tools
F2	"	"	More than 2/3 numerically controlled.

Sections 4.1 to 4.6 below are arranged as follows. First, brief outlines are given of the older and newer processes and main points of difference between them; process-charts are used to represent the successive steps in processing, with the equipment used and the operators involved at each step (these diagrams are omitted from Section 4.6 on the machining of complex parts). Next, the main manpower and skill data are given separately for each process in each of the two firms where they were studied, summarized in tables to show skill-distributions, and diagrammed as skill-profiles for the older and newer technologies. The outcomes of statistical tests intended to establish the reliability of observed differences are given as abridged summaries of analysis of variance. Finally estimates of the educational and on-the-job experience requirements are tabulated and interpreted.

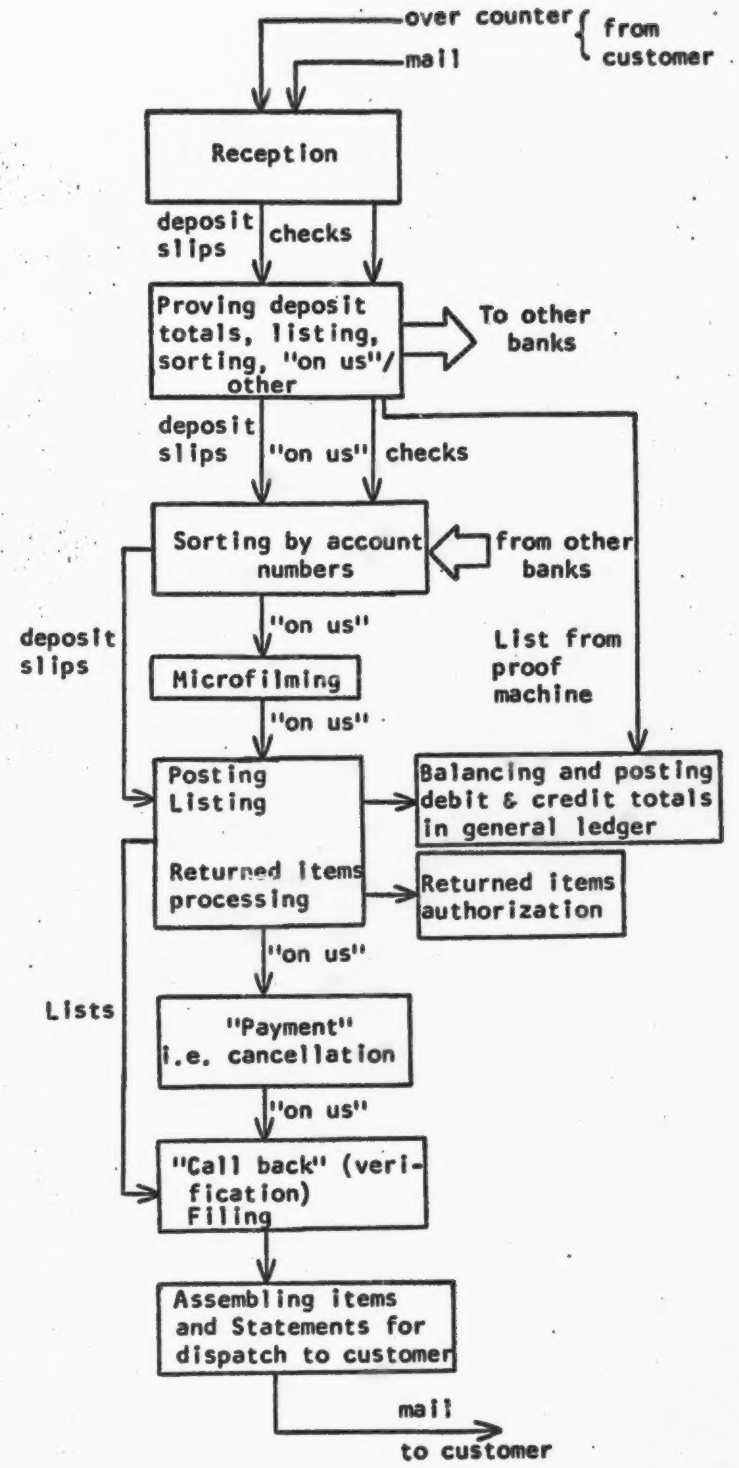
The original field-data and additional supporting material is given in four appendices, one for each of the four processes studied. These include descriptions of the technologies and detailed process descriptions, comparisons of the main characteristics of the products selected with those of the total product mix, the methods used for deriving skill-ratings from the firms' job evaluation schemes, the data used for developing skill input profiles, estimates of the educational and on-the-job experience requirements for every operator, and brief job descriptions.

4.1 Demand-deposit accounting (check-processing and account posting) in multi-branch banks; Studies A1, A2, B1, B2.

Before the advent of electronic computers individual branch offices of banks were in a large measure independently operating units. Checks drawn on a customer's account at any one of these offices were processed on the spot, starting with reception by the teller, through proofing, account posting by the bookkeeper, and final call back (control) by the teller prior to filing. In all essential features, branch offices not yet linked to the computer were found to be still working in this manner. Their operations are highly mechanized in the sense that all the calculations involved in proofing, balancing, recapping, etc. are carried out on calculating and bookkeeping machines or special-purpose adaptations of them; in fact, with the introduction of office machinery (circa 1925) the branch offices must have undergone a revolution quite as extensive as that brought about by the recent installation of computer equipment. For an outline of the four processes see Figures 1-4.

The functions most directly and immediately affected by electronic data processing are bookkeeping, accounting, and the compilation of statistical information for internal control purposes. The transfer of these functions to computers entails an extensive reorganization of the branch office network, with these branch offices forming satellite systems grouped around one or more EDP centers. At branch level there basically remains a need only for the teller function which is so to speak the customer/bank interface, although one of the banks studied continued to perform part of the preparatory sorting and magnetic-ink encoding of debits (checks) and credits (deposit slips) in the branches, whereas the second bank had created special centralized encoding centers.

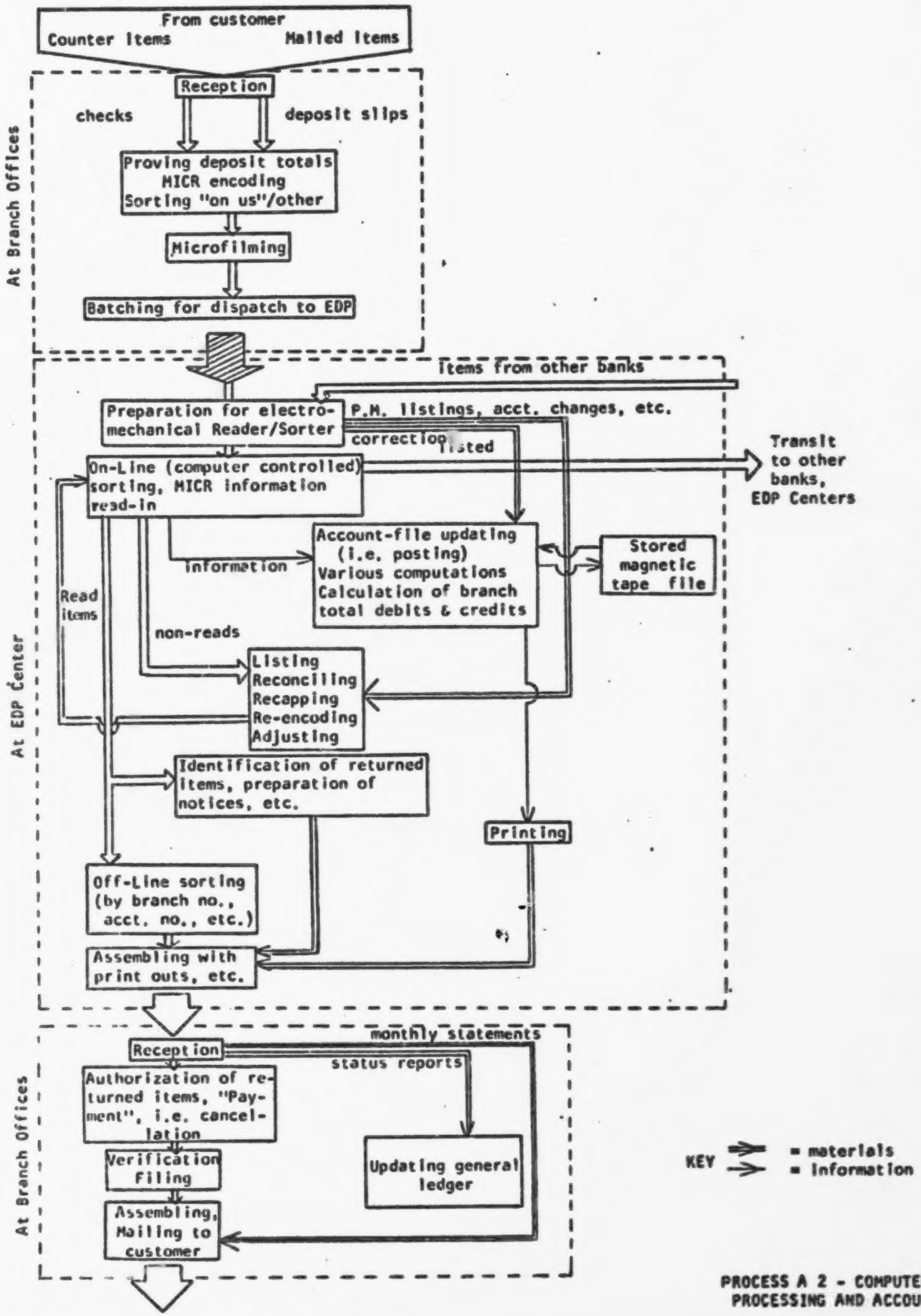
FIGURE 1


over counter
mail
from customer
Reception
deposit slips
checks
Proving deposit totals, listing, sorting, "on us"/ other
To other banks
deposit slips
"on us"
checks
Sorting by account numbers
from other banks
"on us"
deposit slips
List from proof machine
Microfilming
"on us"
Posting Listing
Returned items processing
Balancing and posting debit & credit totals in general ledger
Returned items authorization
"on us"
Lists
"Payment" i.e. cancellation
"on us"
"Call back" (verification) Filing
Assembling items and Statements for dispatch to customer
mail
to customer

MACHINE	OPERATOR
Adding machine	Teller
Proof machine	Proof machine operator
Microfilm machine	Bookkeeper Paying and filing clerk;
Bookkeeping machine (e.g. Burroughs) Adding machine	Bookkeeper
Perforator	Paying and filing clerk
Adding machine	Teller
Postage meter machine	Paying and filing clerk Teller

PROCESS A 1 - MACHINE AIDED CHECK PROCESSING AND ACCOUNT POSTING

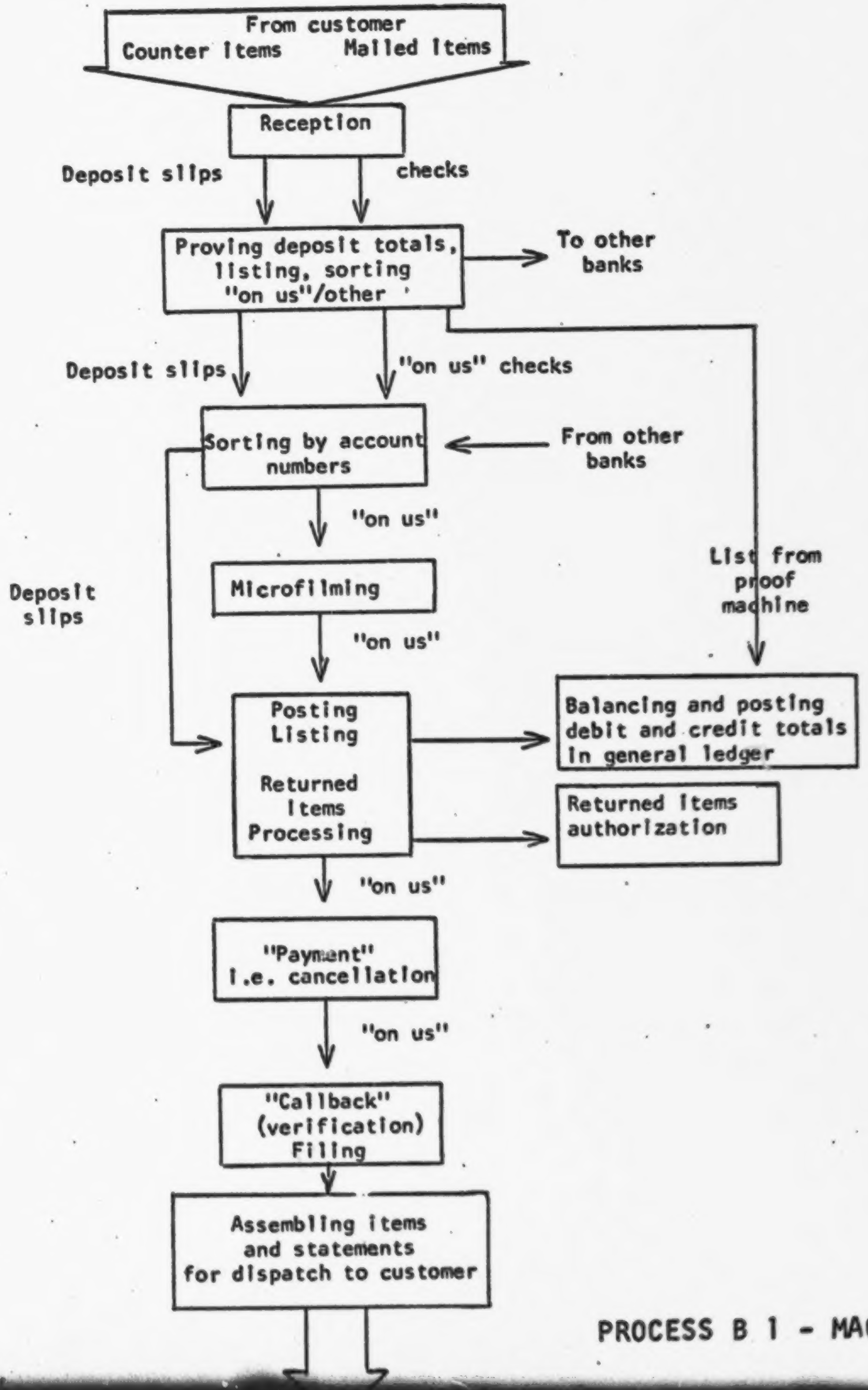
FIGURE 2


From customer
Counter items
Mailed items
At Branch Offices
Reception
checks
deposit slips
Proving deposit totals
MICR encoding
Sorting "on us"/other
Microfilming
Batching for dispatch to EDP
At EDP Center
Items from other banks
Preparation for electro-mechanical Reader/Sorter
P.M. listings, acct. changes, etc.
corrections listed
On-Line (computer controlled) sorting, MICR information read-in
Transit to other banks, EDP Centers
Account-file updating (i.e. posting)
Various computations
Calculation of branch total debits & credits
information
Stored magnetic tape file
Read items
non-reads
Listing
Reconciling
Recapping
Re-encoding
Adjusting
Identification of returned items, preparation of notices, etc.
Printing
Off-Line sorting (by branch no., acct. no., etc.)
Assembling with print outs, etc.
At Branch Offices
Reception
monthly statements
status reports
Authorization of returned items, "Payment", i.e. cancellation
Verification
Filing
Updating general ledger
Assembling, Mailing to customer
KEY
= materials
= information

PROCESS A 2 - COMPUTERIZED CHECK PROCESSING AND ACCOUNT POSTING

MACHINES	OPERATORS
Account number encoder Adding Machine	Teller
Proof machine and MICR Encoder	Proof machine operator
Microfilm machine	P.M. operator
	Messenger Preparation and distribution clerk
Jogger/Reader/Sorting machine (online)	Senior Sorter operator
Computer	Computer operator
Proof machine Flexowriter Adding machine	P.M. operator Flexotypist Reconciler clerks Utility clerks
Off-line page printer Burster Collator	Printer operator
Sorting machine (same as above used offline)	Junior Sorter operator
	Returned items clerk Audit clerk Teller
Perforator Proof machine Adding machine	Proof machine operator General Ledger bookkeeper
	Statement clerk Secretary clerk
	Teller
Postage meter machine	Paying and filing clerk

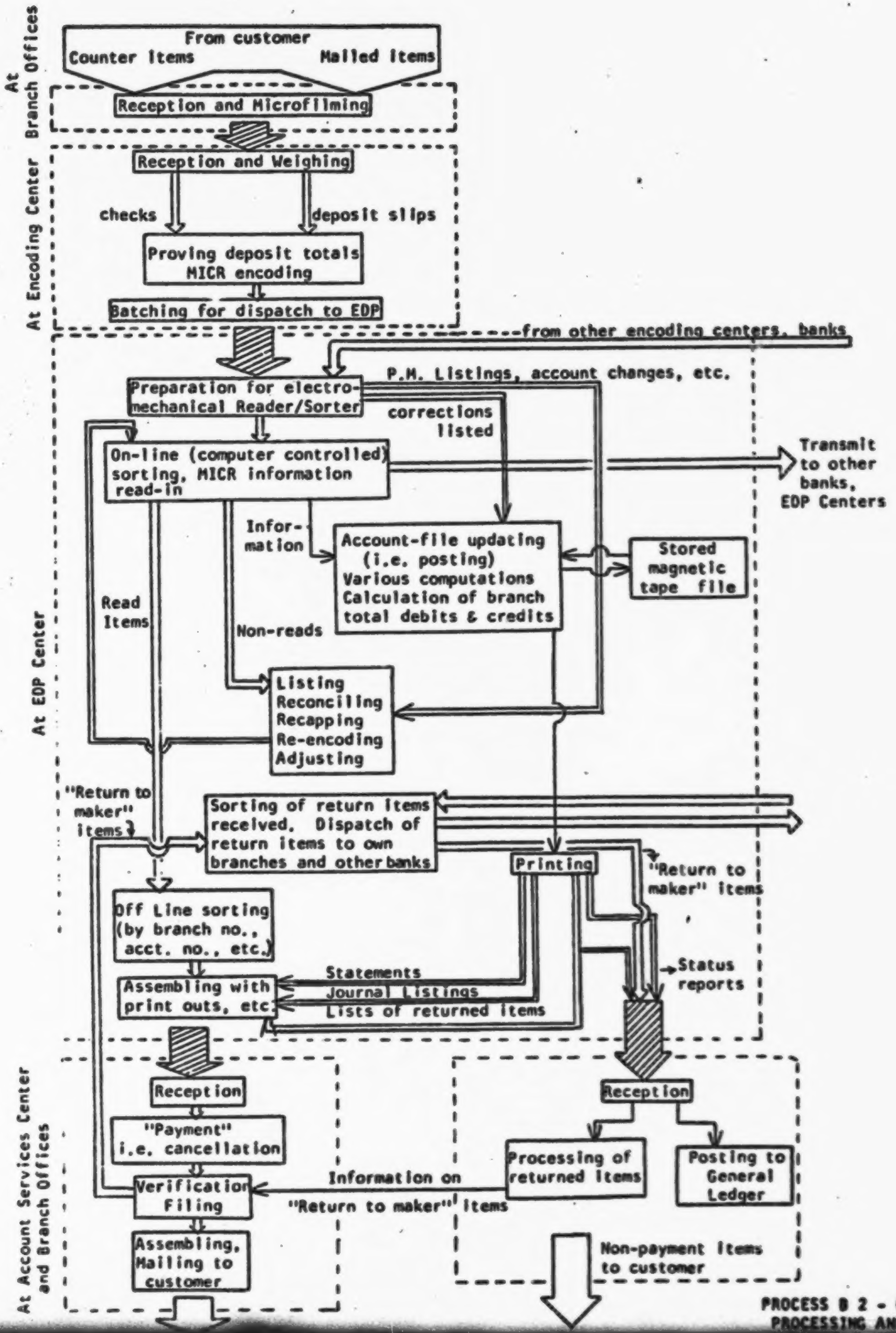
FIGURE 3


From customer
Counter Items
Mailed Items
Reception
Deposit slips
checks
Proving deposit totals, listing, sorting "on us"/other
To other banks
Deposit slips
"on us" checks
Sorting by account numbers
From other banks
"on us"
Microfilming
"on us"
Deposit slips
List from proof machine
Posting
Listing
Returned Items Processing
Balancing and posting debit and credit totals in general ledger
Returned Items authorization
"on us"
"Payment" i.e. cancellation
"on us"
"Callback" (verification) Filing
Assembling items and statements for dispatch to customer

MACHINE	OPERATOR
Adding machine	Teller
Proof machine	Proof machine operator
Microfilm machine	Bookkeeper
Accounting machine Adding machine	Bookkeeper
Perforator	Bookkeeper
Adding machine	Teller
Postage meter machine	Bookkeeper

PROCESS B 1 - MACHINE AIDED CHECK PROCESSING
AND ACCOUNT POSTING

FIGURE 4


At Branch Offices
From customer
Counter Items
Mailed Items
Reception and Microfilming
At Encoding Center
Reception and Weighing
checks
deposit slips
Proving deposit totals MICR encoding
Batching for dispatch to EDP
from other encoding centers, banks
At EDP Center
Preparation for electro-mechanical Reader/Sorter
P.M. Listings, account changes, etc.
corrections listed
On-line (computer controlled) sorting, MICR information read-in
Transmit to other banks, EDP Centers
Infor-mation
Account-file updating (i.e. posting) Various computations Calculation of branch total debits & credits
Stored magnetic tape file
Read Items
Non-reads
Listing Reconciling Recapping Re-encoding Adjusting
"Return to maker" items
Sorting of return items received. Dispatch of return items to own branches and other banks
Printing
"Return to maker" items
Off Line sorting (by branch no., acct. no., etc.)
Statements
Journal Listings
Lists of returned items
Assembling with print outs, etc
Status reports
At Account Services Center and Branch Offices
Reception
"Payment" i.e. cancellation
Verification Filing
Assembling, Mailing to customer
Information on "Return to maker" items
Reception
Processing of returned items
Posting to General Ledger
Non-payment items to customer

PROCESS B 2 - COMPUTERIZED CHECK PROCESSING AND ACCOUNT POSTING

MACHINES	OPERATORS
Adding machines	Tellers Utility clerks Branch clerks Branch steno/receptionists
Microfilm machine	Mail clerks
Scales	Junior clerks Senior clerks Ass't. Section Supervisor (working)
Proof machine and MICR encoder	Proof machine operators
Adding machine	Junior clerks
	Assembler
Jogger Reader/sorting machine	Computer operators
Computer	Computer operators Department clerks Steno/clerks
Flexowriter	Junior clerks
Adding machine Account number encoder	Reconcilers Junior Reconcilers Senior Working Supervisors
Proof machine Printer	Reclamation clerks Computer operators
Jogger Off-line reader/sorters Burster Collator	Fine sort operators Department clerks
	Messengers EDP clerks
Perforators	Utility clerks Department clerks
Automatic filing units Adding machines	Proof-of-deposit clerks
Postage meter machines	Statement clerks Working supervisors

Apart from specialized computer operating personnel, a large number of new kinds of job-functions have come into being, all in close proximity to the computer. These have to do with updating customer account files (kept on magnetic tape), rectifying inaccurate or technically deficient encodings and discrepancies, the return of insufficient-fund items to branches for authorization of payment at the manager's discretion, sorting of items by branch and customer account-number for subsequent dispatch to the originating offices or account servicing centers, etc. A good deal of auxiliary equipment has been installed alongside the computers, especially sorting machines, page-printers and (Bank B) filing machines. The maintenance of most of this equipment and of the computers is performed under contract by the suppliers. Some aspects of the changeover from a manual to a computerized system are shown in the attached simplified process diagrams. More detailed listing of component operations in the various processes are given in Appendix I.

Computerization is reported to have substantially reduced the incidence of human error, as was hoped; indeed this was apparently a significant factor in prompting the decision to automate in Bank A. It has also increased and speeded up the flow of information to management for policy and planning purposes. These gains are not reflected in the data presented below which are simply estimates of the reductions in total manhours per unit.

Changes in manhour requirements by skill-level

In Bank A the manhour input per 1000 items processed in the new system was a little over half its previous value; in Bank B it was down by some 20%. After these reductions (i.e. on the new system) the per-unit manhour requirements for check processing and account posting were about the same in the two firms. As seen below the major portion of the manhour reductions was located in the medium-skill levels, corresponding to bookkeeping and accounting personnel in branch offices.

Comparison of the skill-profiles between old and new technologies (Figures 5,6) and the percentage manhour distributions given in Tables 2 and 3 indicates a distinct change in skill demand, with a net upward shift of 5.9 points (10%) and 8.2 (16%) in mean skill-level for the two banks respectively.

The change in skill distribution was tested for statistical significance by analysis of variance, comparing the manhour inputs at 3 skill levels (lower, medium, higher) and 2 levels of technology and using the consistency between firms as a measure of the reliability of the data. A summary of the analysis is given in Table 4 and more detailed data will be found in Appendix I.

The observed difference between the two banks in total manhours per unit product expended at the lower and higher technological levels did not reach a statistically significant level, a result which confirms the comparability of the two organizations. On the other hand the interaction between skill level and technology level (4th line of Table 4) was great enough to show that the observed increase in skill level from the old to the new technology cannot be due to change (statistically significant at the 20% level). In other words the data provide

TABLE 2

COMPARATIVE SKILL DISTRIBUTIONS - A1 and A2

Organization: Bank A

Process: Check processing and account posting

Technology (Level 1): Machine-aided hand processing

Technology (Level 2): Computerized processing

Source of Data: Direct Observation

Period: Summer 1965

1		2	3	4	5	6	7	8	9	10	11
SKILL LEVEL		SKILL POINT RANGE	MANHOURS PER 1000 ITEMS			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
			TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG.
High	6										
	5	157-	0.0	0.2	+0.2	0.0	1.0	+ 1.0	-	2	+2
	4	130-156	0.0	2.2	+2.2	0.0	14.0	+14.0	-	7	+7
Medium	3	106-129	17.3	9.2	-8.1	57.1	57.5	+ 0.4	1	10	+9
	2	89-105	13.0	3.7	-9.3	42.9	23.1	-19.8	3	4	+1
Low	1	72-88	0.0	0.7	+0.7	0.0	4.4	+ 4.4	-	1	+1
	0	52-71	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
		TOTALS	30.3	16.0	-14.3	100.0	100.0	0.0	4	24	+20
		NET % MANHOUR CHANGE - 47.2%									

	Mean Skill Level	Standard Deviation
Technology (Level 1)	112.3	7.9
Technology (Level 2)	118.2	17.2
Change	+5.9	

TABLE 3

COMPARATIVE SKILL DISTRIBUTIONS - B1 and B2

Organization: Bank B

Process: Check processing and account posting. Production unit 1000 items posted.

Technology (Level 1): Machine-aided hand processing

Technology (Level 2): Computerized processing

Source of Data: Direct observation

Period: Winter 1965

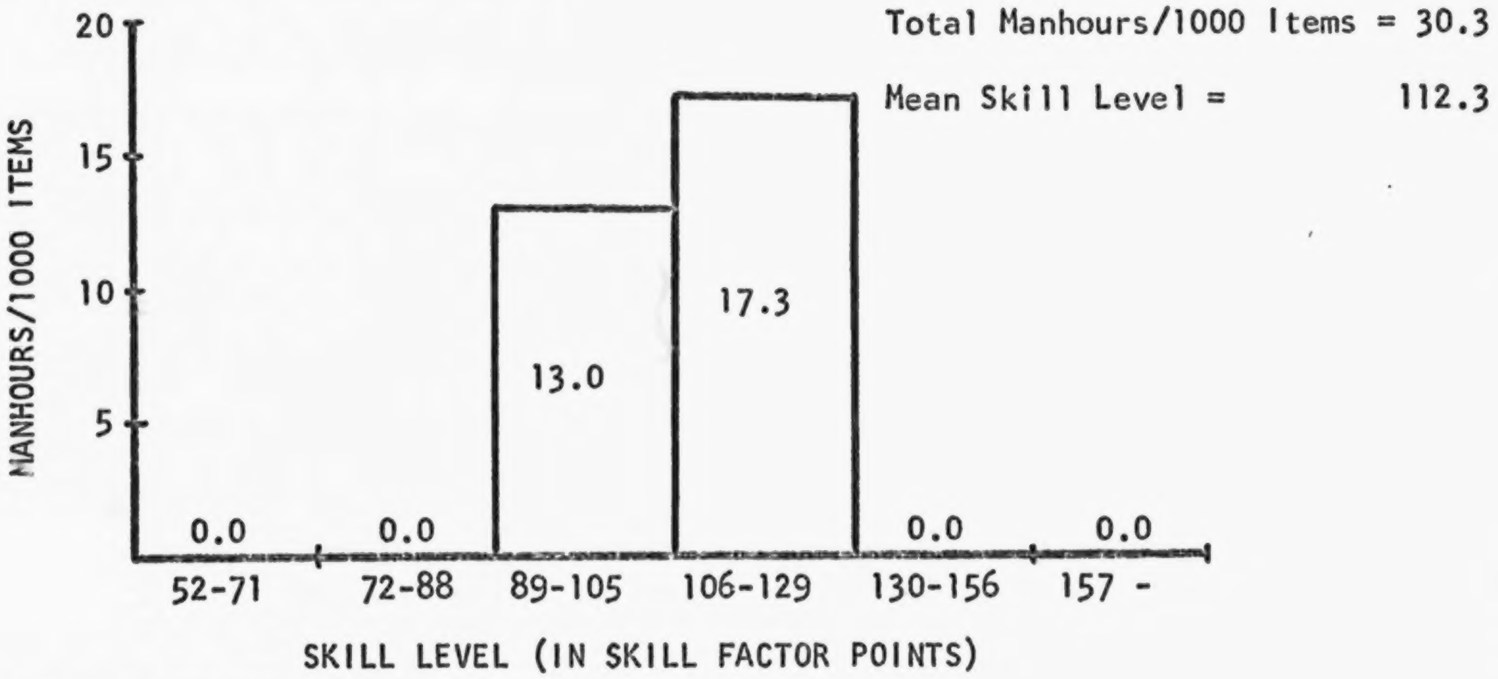
1	2	3	4	5	6	7	8	9	10	11
SKILL LEVEL	SKILL POINT RANGE	MANHOURS PER 1000 ITEMS			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
		TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG
High 6										
5	157-	0.0	1.0	+1.0	0.0	6.1	+6.1	-	12	+12
4	130-156	0.0	0.6	+0.6	0.0	3.5	+3.5	-	11	+11
Medium 3	106-129	10.3	9.7	-0.6	47.8	57.0	+9.2	1	29	+28
2	89-105	11.2	5.0	-6.2	52.2	29.4	-22.8	3	18	+15
Low 1	72-88	0.0	0.7	+0.7	0.0	4.0	+4.0	-	8	+8
0	52-71	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	TOTALS	21.5	17.0	-4.5	100.0	100.0	0.0	4	78	+74
	NET % MANHOUR CHANGE -20.9%									

	Mean Skill Level	Standard Deviation
Technology (Level 1)	103.9	3.2
Technology (Level 2)	112.1	17.1
Change	+8.2	

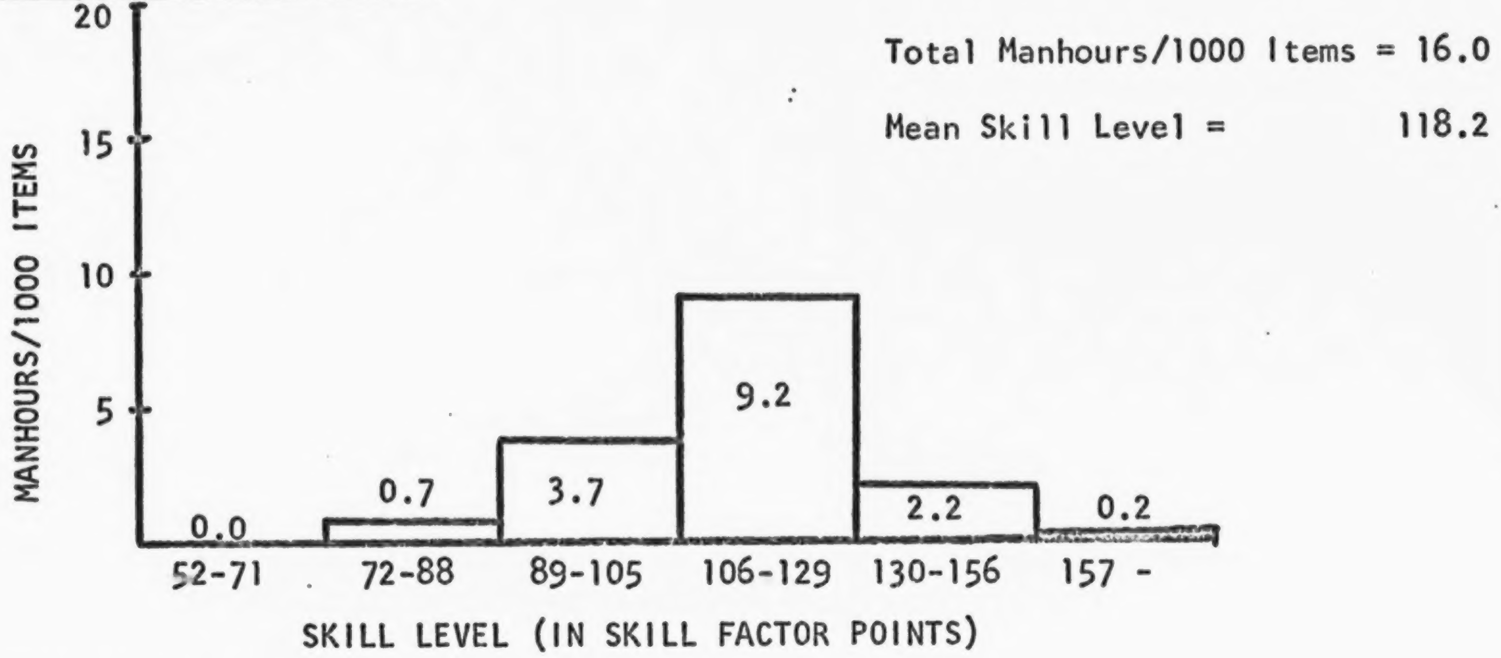
FIGURE 5

.COMPARATIVE SKILL PROFILES - A1 and A2

MACHINE AIDED HAND PROCESSING



COMPUTERIZED PROCESSING



CHANGES - OLD TO NEW TECHNOLOGY

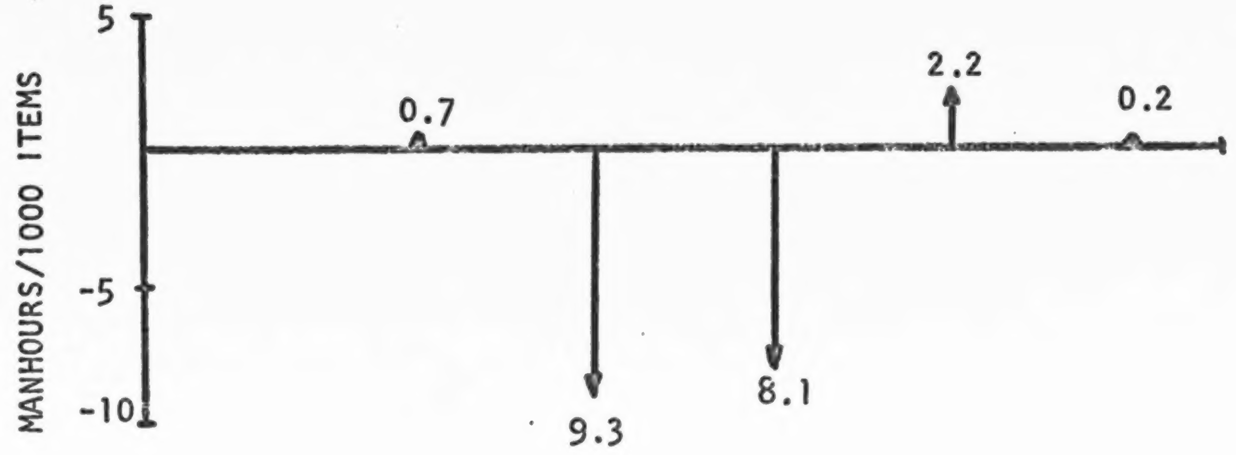
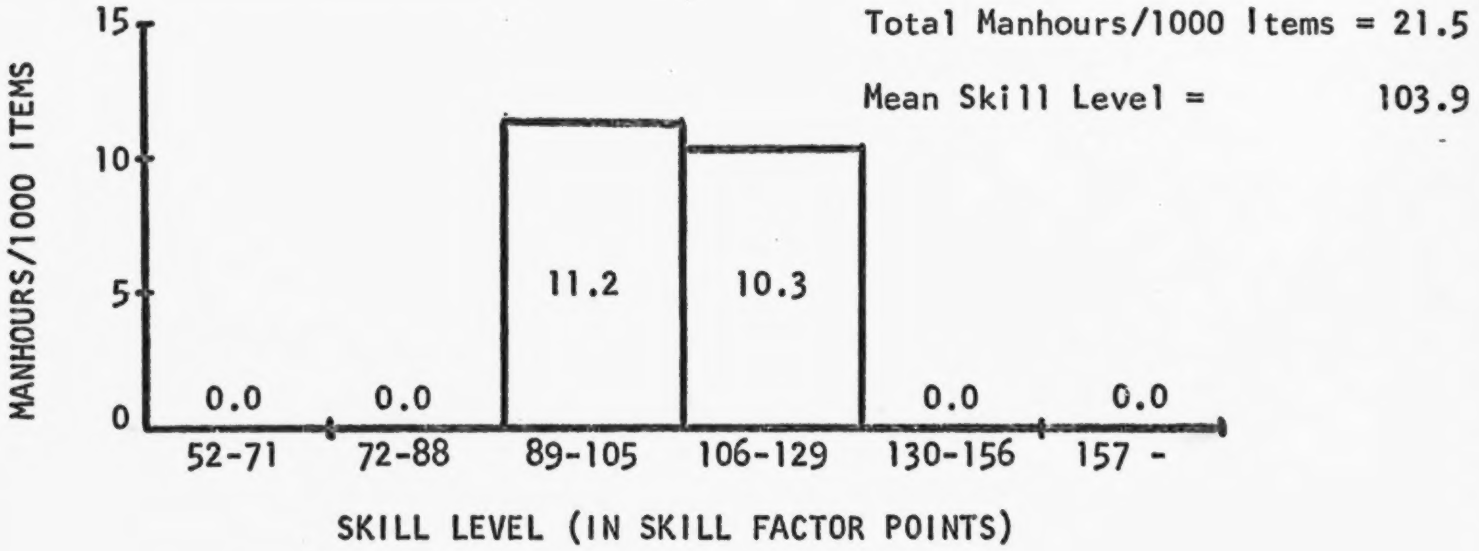


FIGURE 6

COMPARATIVE SKILL PROFILES - B1 and B2

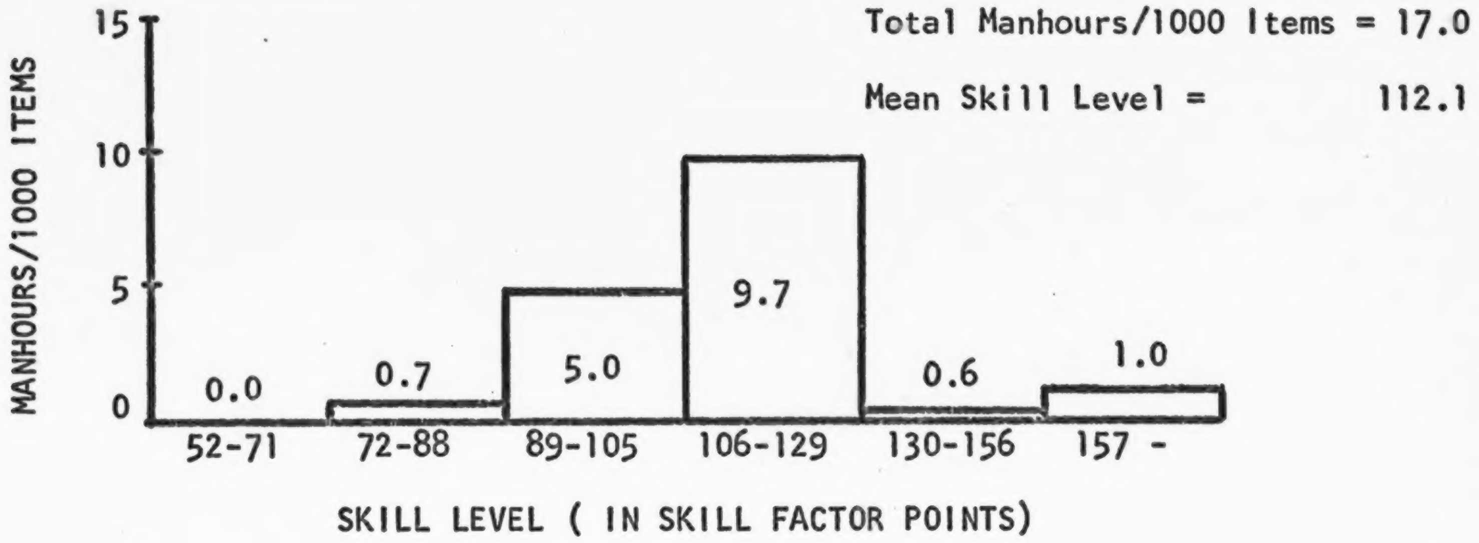
MACHINE AIDED HAND PROCESSING



Total Manhours/1000 Items = 21.5

Mean Skill Level = 103.9

COMPUTERIZED PROCESSING



Total Manhours/1000 Items = 17.0

Mean Skill Level = 112.1

CHANGES - OLD TO NEW TECHNOLOGY

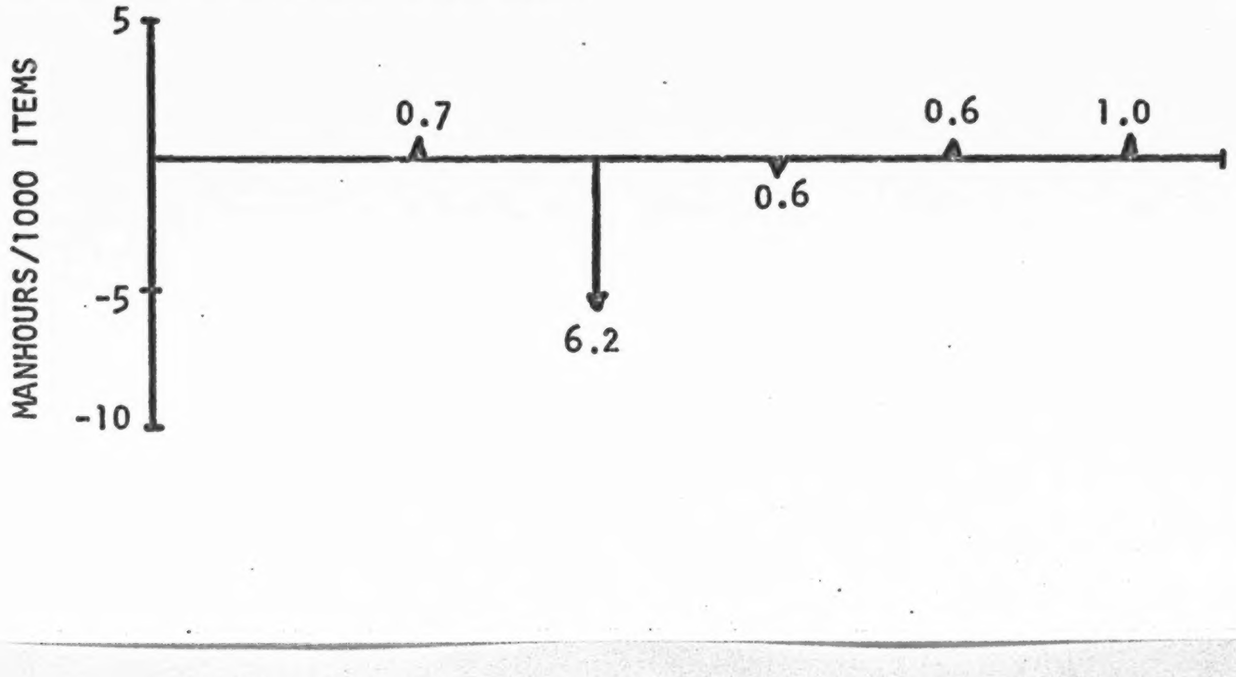


TABLE 4

Statistical test of the difference between technological levels in check-processing and account-posting.

Manhour data, Banks A and B, 1965

Source of Variance	D.F.	V.R.	Significance level
Between skill levels	2	126.3	P<0.01
Between technologies	1	5.8	
Between firms	1	2.0	
SL x T	2	26.3	P< 0.05
SL x F	2	1.5	
T x F	1	8.8	

sound evidence that the technological change has had a real effect on skill-requirement. The difference is not so much due to an increase in requirements at the higher skill level as to a substantial drop at the medium skill level; however a small absolute increase is observed at the higher levels.

Changes in skill-content

The number of job-types increased considerably in both banks, indicating a greater spread of skill-contents, but the observed rise may overestimate the actual change since not all of the job-types existing in the older technology were represented in the relatively small branches where the studies were conducted. A clue to the actual increase in number of job types with changing technology is, however, obtainable from Table 7 in Section 4.2, where comparable data are given for the whole demand-deposit accounting system of Bank A before and after computerization of its major operations. The recorded changes in numbers of job types at each skill level further show that a substantial number of the newly created jobs were at the highest skill categories, accounting for some 30-50% of the total.

Changes in educational and on-the-job experience requirements

Tables 5 and 6 were derived by averaging the estimates given separately for Banks A and B in Appendix 1. As is evident from the unchanged mean educational levels, the basic educational requirements of the computerized technology are on average no higher than were those for the displaced technology, i.e., about two years of high school. The last three columns of Table 5 indicate that more than 2 years of high school are typically required, inasmuch as more than 50% of the total manhours in the older as well as of the newer technologies fall into the top group.

The mean estimated requirements for duration of on-the-job experience, less in absolute terms than education required, have risen slightly from 3 to nearly 4 months (Table 6). This rise is mainly attributable to the demand in the computerized technology for personnel with 6-18 months of on-the-job experience to the extent of 8% of the total manhours, while the experience demanded of the remainder of the labor-force remains unchanged.

Altogether the computerized system differs little from the older system either in its demands for basic education or for on-the-job experience. The increases in mean-skill level that were found to be associated with the introduction of the newer technology are due partly to longer on-the-job experience needed by a relatively small proportion of the total manpower and partly to reduced demand at lower levels. Since the basic educational requirements of the majority of the personnel remain virtually unchanged, it can be argued that, given more job experience, at least half of all the direct labor currently employed would be capable of reaching skill levels sufficiently high to meet the specifications of the most complex tasks in the system.

4.2 Overall changes in manpower at Bank A

In addition to sample data obtained in Bank A by direct observation of one of its branch offices not yet integrated into the EDP system, and of a branch office plus EDP installation representing the newer technology, the bank's officers kindly made available extensive records reflecting the total volume of items processed and posted to customers' accounts, as well as the total manhour inputs before and after computerization of the demand-deposit bookkeeping operations for the bank as a whole. As the job evaluation scheme has remained unchanged, it was possible to compute skill-distributions and draw up skill-profiles for the whole bank exactly as was done in Section 4.1 above, and to use these to verify the results obtained by direct observation of representative part sectors of the bank shown in the tables and figures for studies A1 and A2. The results of studies A3 and A4 whown in Table 7 and Figure 7 can thus be regarded as replications of A1 and A2 on a larger scale.

Comparison of the skill-profiles for the direct and indirect data (Figures 5,7) indicates that the agreement is good in several respects:

1) The mean skill levels are virtually identical both for the older (A1 and A3) and for the newer technologies (A2 and A4).
2) The total manhours per unit product are almost exactly the same for the older technology (A1 and A3).
3) The manhours per unit product are similar at each skill level for the newer technology (A2 and A4).
4) With one exception, the manhours per unit product are also very similar at each skill level for the newer technology (A2 and A4).

It is this one exception -- the difference between the manhour inputs in the 106-129 skill-factor-point range -- which accounts for the large difference between the productivity rises shown in the two studies. Whereas the total inputs in the direct observation study dropped by 14.3 manhours per unit product, the decrease was only 8.4 manhours per unit product for the whole system as reflected in the company records.

Follow-up inquiries to account for this discrepancy showed that it was largely due to peculiarities in the labor market accessible to the EDP-linked branch office selected for the A2 study, and the resourcefulness of the operations manager of this branch in taking advantage of these peculiarities, the net effect being that a substantially higher proportion of tellers (skill factor point rating = 119) were employed on a part-time basis than is typical of the average branch in Bank A. In this respect our initial sample was unrepresentative of the bank as a whole.

Comparison of Tables 2 and 7 also reveals sizeable differences between the number of job types at the two technological levels as determined by direct observation and as reported in the records for the bank system as a whole. For convenience these totals and differences are summarized in Table 8.

TABLE 5: ESTIMATED REQUIRED HIGH SCHOOL EDUCATION, BANKS A & B

High School Education (years)	Average Manhours Per 1000 Items			Average Manhours as % of Total for each Technology Level		
	TL 1	TL 2	Change	TL 1	TL 2	Change
2.1-4.0	14.7	9.5	-5.2	56.9	60.1	+3.2
0.1-2.0	11.2	5.7	-5.5	43.1	36.0	-7.1
0	0.0	0.6	+0.6	0.0	3.9	+3.9

	TL 1	TL 2
MEAN EDUCATIONAL LEVEL (Years of High School)	2.1	2.2

TABLE 6: ESTIMATED REQUIRED ON-THE-JOB EXPERIENCE, BANKS A & B

On-the-job Experience (Months)	Average Manhours Per 1000 Items			Average Manhours as % of Total for each Technology Level		
	TL 1	TL 2	Change	TL 1	TL 2	Change
13-18	0.0	0.1	+0.1	0.0	0.4	+0.4
6-12	0.0	1.2	+1.2	0.0	7.6	+7.6
4-6	10.7	6.3	-3.4	41.4	40.2	-1.2
1-3	13.0	7.2	-6.8	50.2	45.9	-4.3
0.3-0.8	2.2	0.6	-1.6	8.4	3.9	-4.5
0-0.3	0.0	0.4	+0.4	0.0	2.5	+2.5

	TL 1	TL 2
MEAN LENGTH OF EXPERIENCE (Months)	3.1	3.7

TABLE 7

COMPARATIVE SKILL DISTRIBUTIONS - A3 and A4

Organization: Bank A

Process: Check Processing and Account Posting

Technology (Level 1): Machine-Aided Hand Processing, whole Bank (1957)

Technology (Level 2): Computerized Processing, whole Bank (1965)

Source of Data: Supplied by Firm

Period: 1957 and 1965

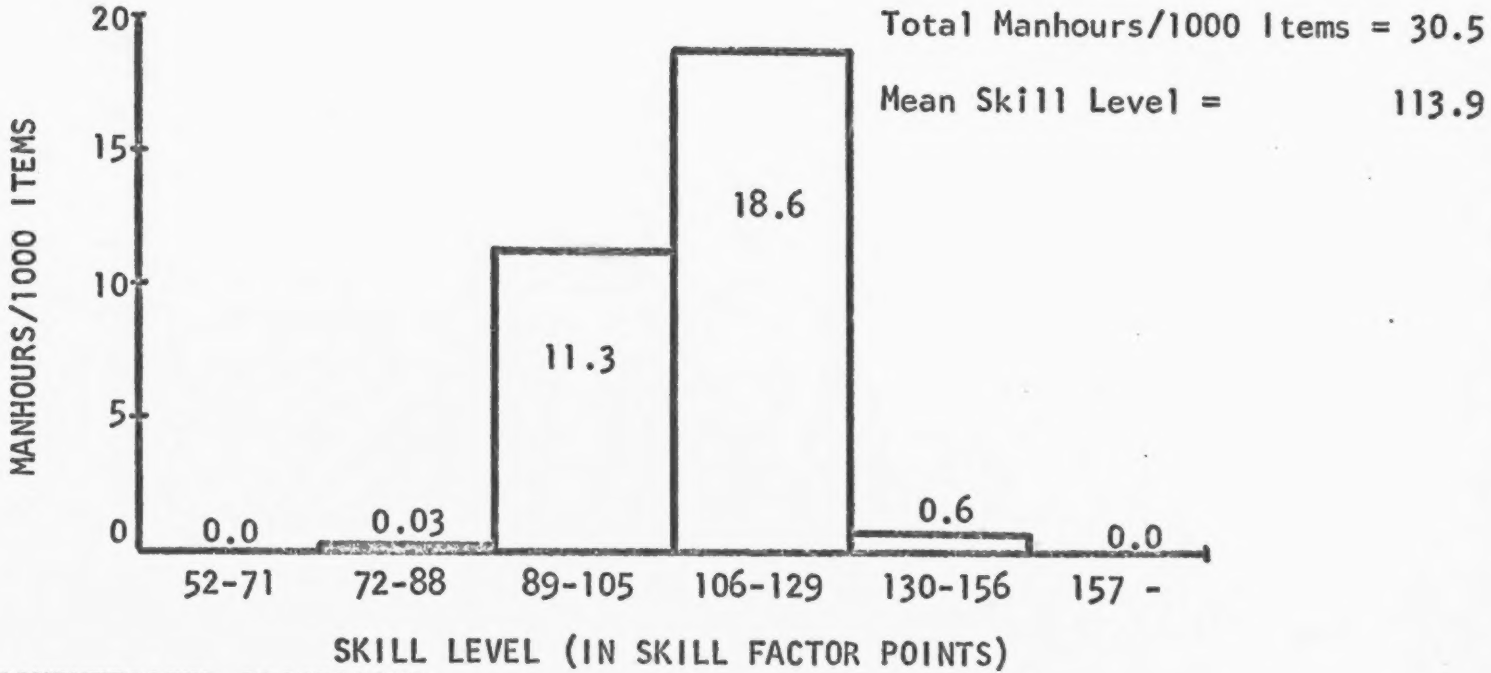
1		2	3	4	5	6	7	8	9	10	11
SKILL LEVEL		SKILL POINT RANGE	MANHOURS PER 1000 ITEMS			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
			TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG.
High	6										
	5	157-	0.0	0.4	+0.4	0.0	1.8	+1.8	-	6	+6
	4	130-156	0.6	1.7	+1.1	2.0	7.7	+5.7	4	9	+5
Medium	3	106-129	18.6	15.6	-3.0	61.0	70.6	+9.6	5	15	+10
	2	89-105	11.3	4.4	-6.9	37.0	19.9	-17.1	2	12	+10
Low	1	72-88	0.03	0.02	-0.01	0.0	0.0	0.0	2	2	0
	0	52-71	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
		TOTALS	30.5	22.1	-8.4	100.0	100.0		13	44	+31
		NET % MANHOUR CHANGE -27.5%									

	Mean Skill Level	Standard Deviation
Technology (Level 1)	113.9	8.3
Technology (Level 2)	119.1	15.5
Change	+5.2	

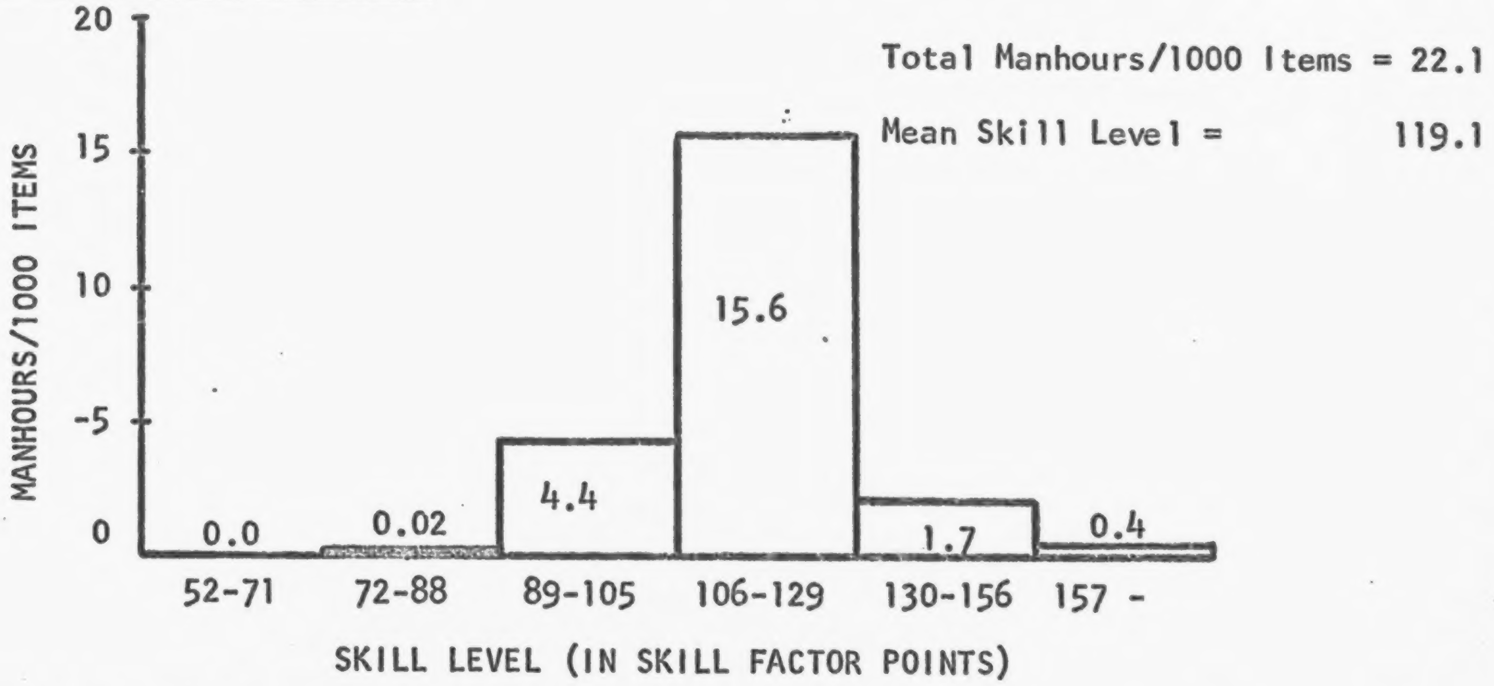
FIGURE 7

COMPARATIVE SKILL PROFILES - A3 and A4

MACHINE AIDED HAND PROCESSING



COMPUTERIZED PROCESSING



CHANGES - OLD TO NEW TECHNOLOGY

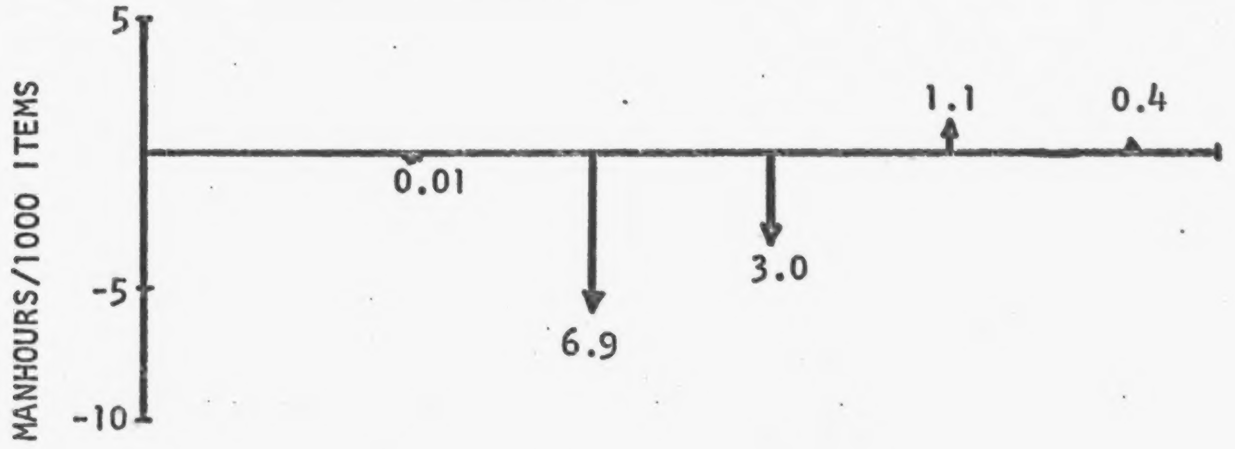


TABLE 8

Number of job types counted in Studies A1,2 and A3,4

Study	Method	Number of Job Types		
		TL 1	TL 2	Difference
A1,2	Direct observation	4	24	20
A3,4	Bank's records	13	46	33

These discrepancies were readily accounted for by the fact that the direct observation study only covered a limited sector of the total demand-deposit accounting systems. In their particular sectors the local managements have found it possible to combine several functions under a limited number of job titles: for some of the tasks performed by tellers in a small branch, for example, a larger branch will find it justifiable to employ special ledger clerks, filing clerks, utility clerks, etc. Similarly there was a greater functional differentiation in the larger EDP Centers. Furthermore, as the type of customer and business dealt with differs from location to location, clerical personnel of different specialization will be employed in each. These variations make data on numbers of job types relatively unreliable guides to the actual skill-demands of different processes.

It is tempting to infer from the large increase in number of job types associated with the introduction of computer technology also observed in Bank B, that the need for economic utilization of expensive computer equipment has compelled greater specialization in the interest of efficiency. No doubt this is part of the explanation. But there were also indications that this need has been over-estimated. Instances were reported in both banks where the trend is undergoing reversal and where over-narrowly conceived task groups (jobs) are being recombined into larger groupings. This same reversal was also manifest in the increasing and not unsuccessful efforts by managements at all levels of the system to rotate jobs and to substitute part-time for full-time labor.

4.3 Box and continuous annealing of steel strip (Studies C1,C2,D1,D2)

The traditional process of annealing consists in stacking decks of sheets or coils of strip on flat bases, placing covers over them, then lowering a portable, box-like furnace on top of the stacks, connecting gas and air pipework on the furnace to supply points close to each base, lighting the furnace and putting the material through an annealing cycle with three phases, termed respectively firing, soaking and cooling. At the end of the soaking phase (see Figure 8 for process-chart) the portable furnace is lifted off and transferred to another stack. The handling of sheets or coils and the transportation of covers and furnaces is mechanized, but nearly all other operations are manual. Once the crew has completed stacking and covering and the furnace has been lit, the process requires no supervision apart from occasional adjustments by the chief operators. The crew moves to other bases to assist in the removal of furnaces or to carry out sundry operations concerned with preparation, cleaning, equipment inspection and minor repair tasks.

In many steelworks where the newer process of continuous annealing (Figure 9) has been introduced, further box annealing capacity is being installed and there is some difference of opinion in the industry as to whether continuous annealing is likely to displace the batch process altogether. Technologically the newer process represents an undoubted advance through implementation of the continuous-flow principle, its chief feature being that the strip is constantly on the move as it undergoes heat treatment. The necessary extra operations of uncoiling the strip, welding it end to end and re-coiling after annealing, are highly mechanized. Temperature and atmospheric control of the heating and cooling towers is largely automatic(with manual over-ride options) and so also is the inspection for certain types of defect carried out at the exit end of the line. Only the removal of tangled strip ("cobbles") after breaks and the re-threading of strip through the mill remain fully manual operations; though the occurrence of breaks is infrequent, when they do occur they make considerable demands on operators in terms of physical exertion and initiative. For further details of the two processes see Appendix II.

Changes in skill-requirements

The reduction in per-unit requirements resulting from the introduction of continuous annealing were of the same order in both steelworks - 36% in one and 38% in the other (see Tables 9,10 and Figures 10, 11). The manhours required at the lowest and some of the medium skill levels had been completely eliminated in the newer process and there were reductions in manhours at some of the higher levels as well.

The mean skill level rose by 0.7 points (23%) in Firm C and 0.3 points (9%) in Firm D. The change in distribution of skill levels was tested for statistical significance by analysis of variance of manhour inputs, skills being grouped into 3 levels at the 2 levels of technology. The consistency between firms was then used as a measure of reliability (see Table 11 for summary).

The difference between the firms in the total number of manhours going into the older and newer processes taken together was not statistically significant and they can therefore be regarded as comparable. The interaction between skill-level and technology was significant at the 20% level and the observed increase in mean skill from the older to the newer technology is therefore unlikely to have arisen by chance. Inspection of the profiles suggests that these increases were not due so much to added requirements at higher skill levels manhours, as to relative reductions in manhours at medium skill levels.

Changes in skill content

The number of job-types decreased in both firms, indicating a reduction in spread of skill content.

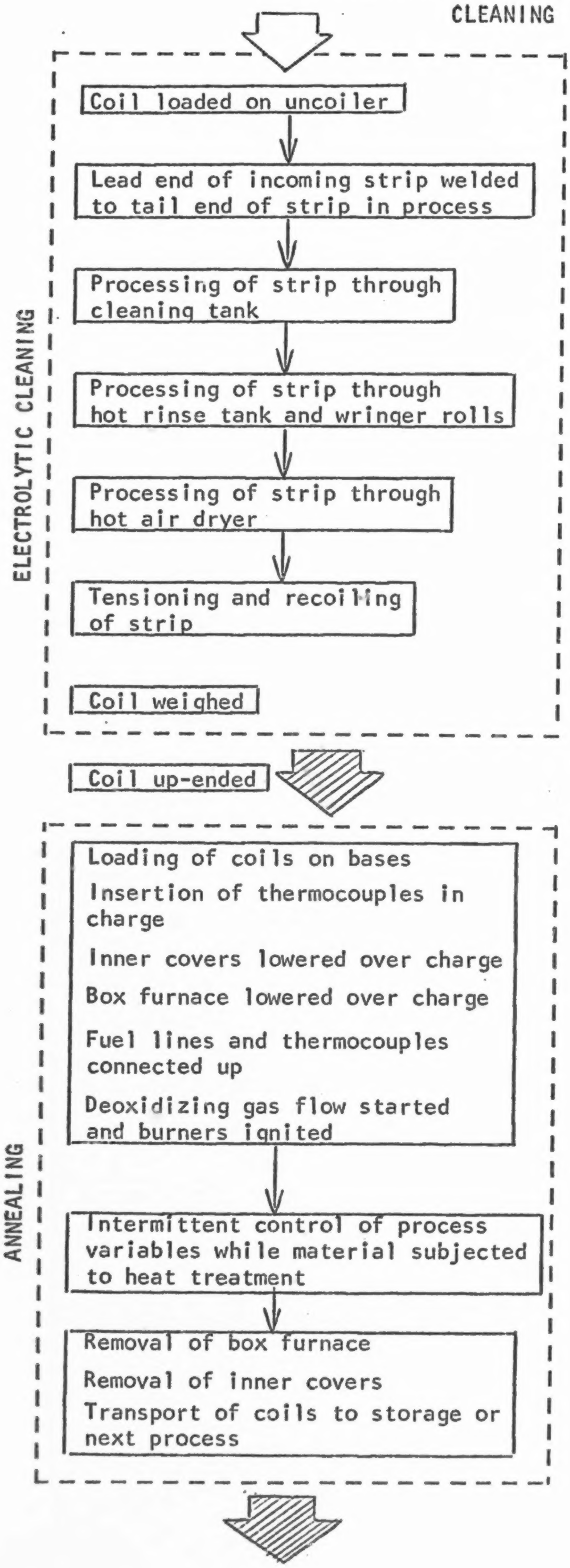
Changes in educational and on-the-job experience requirements

The estimates of educational and on-the-job experience requirements listed for individual operators in Appendix II were used to compute the averages shown in Tables 12 and 13, for Firms C and D taken together.

Although the mean educational level required,expressed in years of high-school completed,rose from about half a year for the older process to near 2 years for the newer; reference to the last three columns of Table 12 shows that over 60% of all labor-time at both technology levels required no high-school education at all. The small net rise in the overall education level of the workforce was due to an increase of some 20% in the manhours requiring 2 - 4 years of high schooling.

FIGURE 8

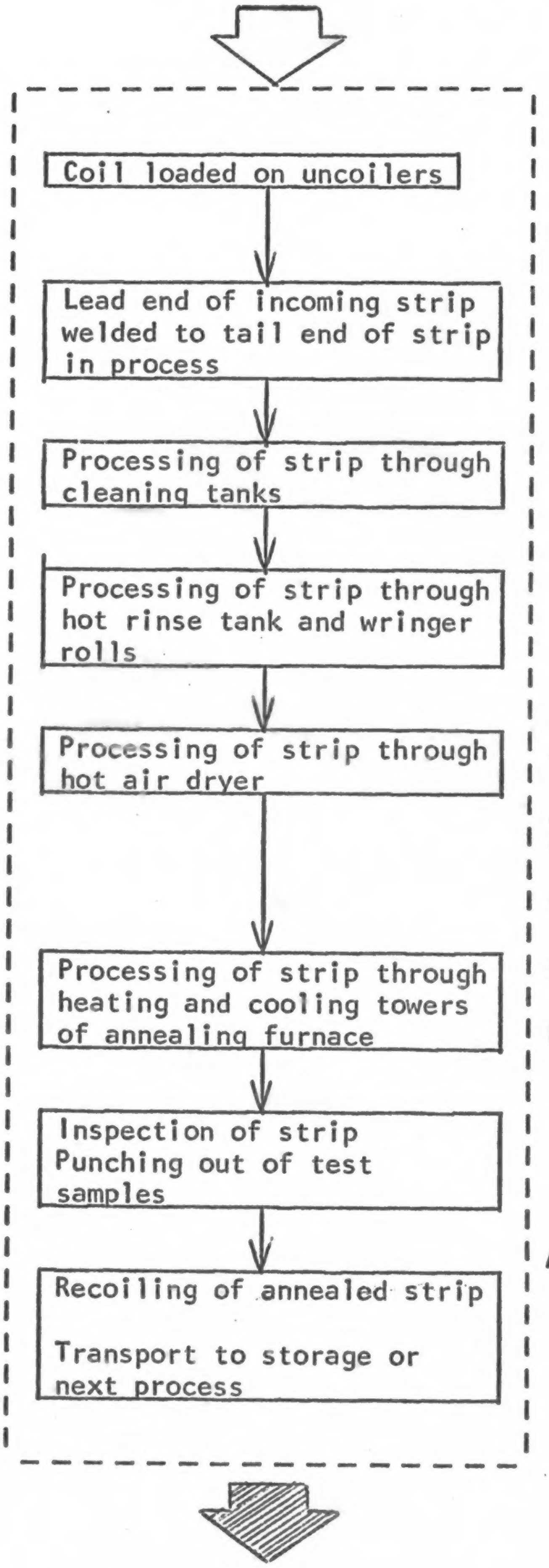
C1, D1: BOX ANNEALING INCLUDING ELECTROLYTIC CLEANING


ELECTROLYTIC CLEANING
Coil loaded on uncoiler
Lead end of incoming strip welded to tail end of strip in process
Processing of strip through cleaning tank
Processing of strip through hot rinse tank and wringer rolls
Processing of strip through hot air dryer
Tensioning and recoiling of strip
Coil weighed
Coil up-ended
ANNEALING
Loading of coils on bases
Insertion of thermocouples in charge
Inner covers lowered over charge
Box furnace lowered over charge
Fuel lines and thermocouples connected up
Deoxidizing gas flow started and burners ignited
Intermittent control of process variables while material subjected to heat treatment
Removal of box furnace
Removal of inner covers
Transport of coils to storage or next process

C1	D1
Coil feeder (welder)	Welding machine operator
Coil feeder helper	Feeder
Utility tractor operator	Tractor operator
Coil cleaner	Strip cleaner
	Coiler
Tractor operator	Tractor operator
Tow tractor operator	
Floorman	Floorman
Annealing craneman	Process craneman
Utility man	Heat treater helper
Box annealer operator	Heat treater
Stocker	

FIGURE 9

C2, D2: CONTINUOUS ANNEALING INCLUDING ELECTROLYTIC CLEANING


Coil loaded on uncoilers
Lead end of incoming strip welded to tail end of strip in process
Processing of strip through cleaning tanks
Processing of strip through hot rinse tank and wringer rolls
Processing of strip through hot air dryer
Processing of strip through heating and cooling towers of annealing furnace
Inspection of strip Punching out of test samples
Recoiling of annealed strip
Transport to storage or next process

C2	D2
Annealing line feeder	Coil feeder (welder)
Annealing line operator	Annealing line operator
Assistant annealing line operator	Assistant annealing li operator
Tractor operator	
Stocker tractor operator	Annealing line helper
Utility tractor operator	
Annealing line coiler	Coiler

TABLE 9

COMPARATIVE SKILL DISTRIBUTIONS - C1 and C2

Organization: Steelworks C

Process: Annealing Product Unit: 10 tons

Technology (Level 1): Box (Batch) process

Technology (Level 2): Continuous process

Source of Data: Direct observation

Period: Fall 1965

1		2	3	4	5	6	7	8	9	10	11
SKILL LEVEL		SKILL POINT RANGE	MANHOURS PER 10 TONS			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
			TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG
High	6	5.5-6.4	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	5	4.5-5.4	0.3	0.2	-0.1	14.3	15.4	+ 1.1	1	1	0
	4	3.5-4.4	0.1	0.2	+0.1	4.8	15.4	+10.6	1	1	0
Medium	3	2.5-3.4	1.6	0.9	-0.7	76.2	69.2	- 7.0	8	5	-3
	2	1.5-2.4	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
Low	1	0.5-1.4	0.0	0.0	0.1	4.8	0.0	- 4.8	1	-	1
	0	0.0-0.4	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
		TOTALS	2.1	1.3	-0.8	100.0	100.0	0.0	11	7	-4
		NET % MANHOUR CHANGE -38.1%									

	Mean Skill Level	Standard Deviation
Technology (Level 1)	3.0	0.9
Technology (Level 2)	3.7	0.9
Change	+0.7	

TABLE 10

COMPARATIVE SKILL DISTRIBUTIONS - D1 and D2

Organization: Steelworks D

Process: Annealing Product Unit: 10 tons

Technology (Level 1): Box (Batch) process

Technology (Level 2): Continuous process

Source of Data: Direct Observation

Period: Fall 1965

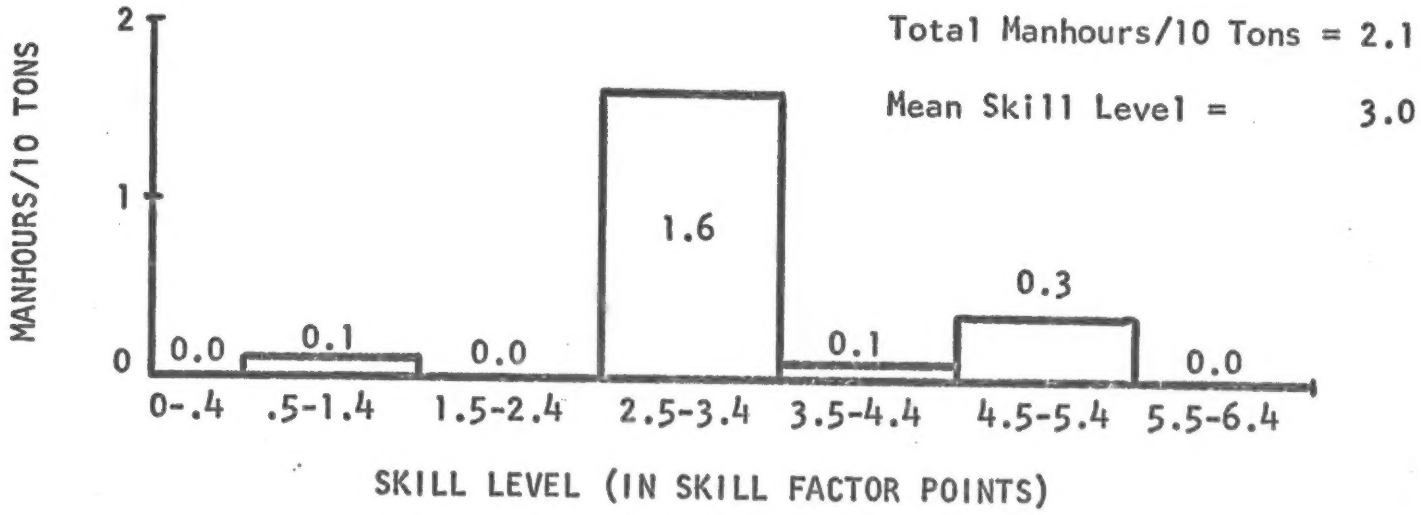
1	2	3	4	5	6	7	8	9	10	11
SKILL LEVEL	SKILL POINT RANGE	MANHOURS PER 10 TONS			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
		TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG.
High 6	5.5-6.4	0.6	0.0	-0.6	24.0	0.0	-24.0	2	-	-2
5	6.5-5.4	0.0	0.3	+0.3	0.0	18.8	+18.8	-	1	+1
4	3.5-4.4	0.2	0.3	+0.1	8.0	18.8	+10.8	1	1	0
Medium 3	2.5-3.4	1.1	1.0	-0.1	44.0	62.5	+18.5	5	3	-2
2	1.5-2.4	0.6	0.0	-0.6	24.0	0.0	-24.0	2	-	-2
Low 1	0.5-1.4	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
0	0.0-0.4	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	TOTALS	2.5	1.6	-0.9	100.0	100.0	0.0	10	5	-5
	NET % MANHOUR CHANGE	-36.0%								

	Mean Skill Level	Standard Deviation
Technology (Level 1)	3.4	1.4
Technology (Level 2)	3.7	0.9
Change	+0.3	

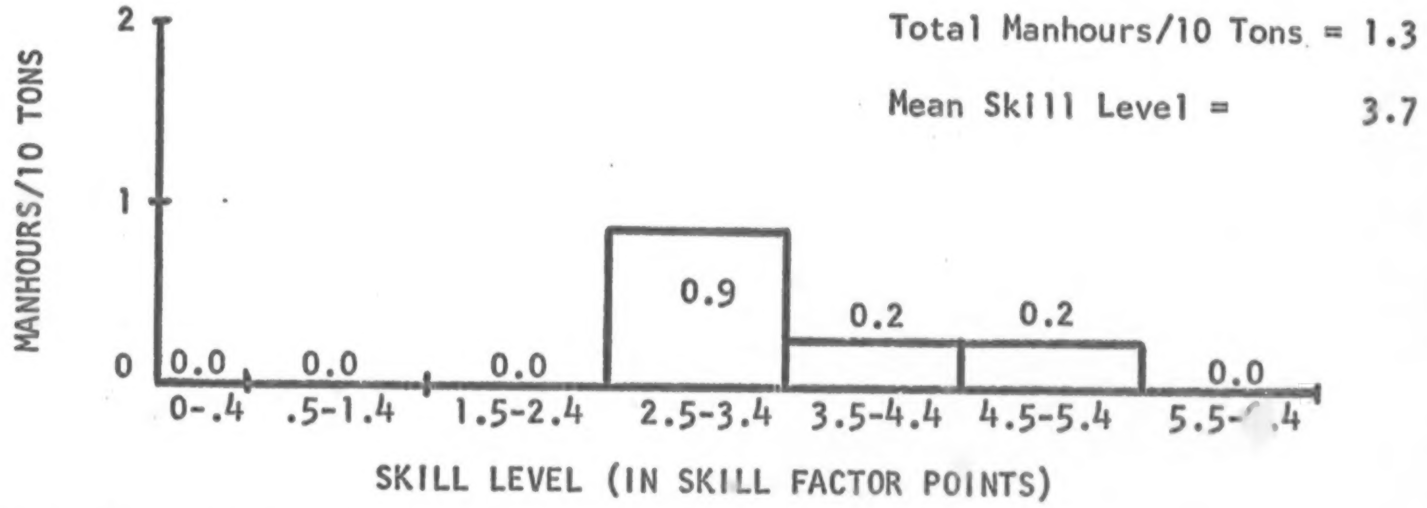
FIGURE 10

COMPARATIVE SKILL PROFILES - C1 and C2

BOX (BATCH) ANNEALING PROCESS



CONTINUOUS ANNEALING PROCESS



CHANGES - OLD TO NEW TECHNOLOGY

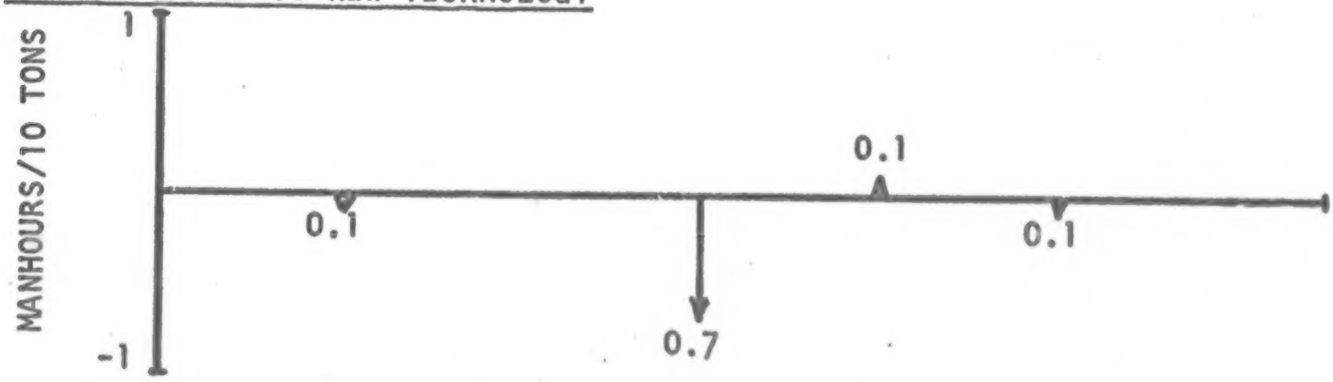
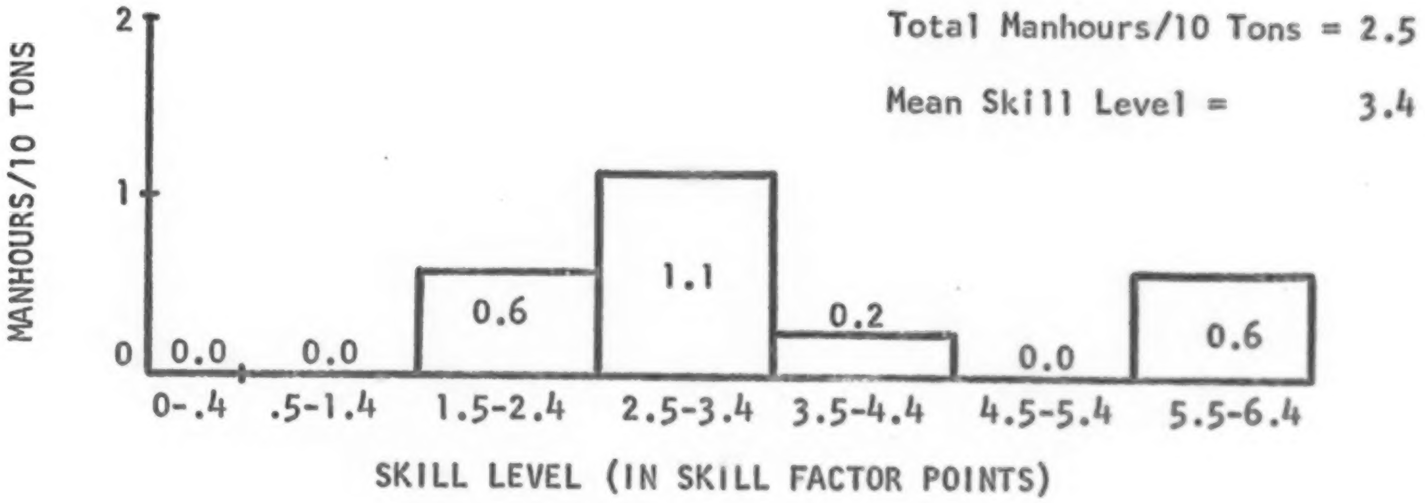


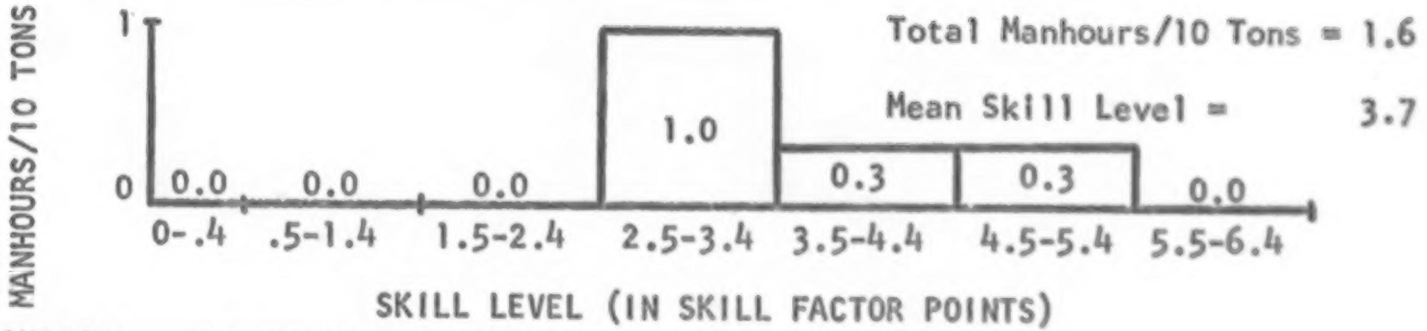
FIGURE 11

COMPARATIVE SKILL PROFILES - D1 and D2

BOX (BATCH) ANNEALING PROCESS



CONTINUOUS ANNEALING PROCESS



CHANGES - OLD TO NEW TECHNOLOGY

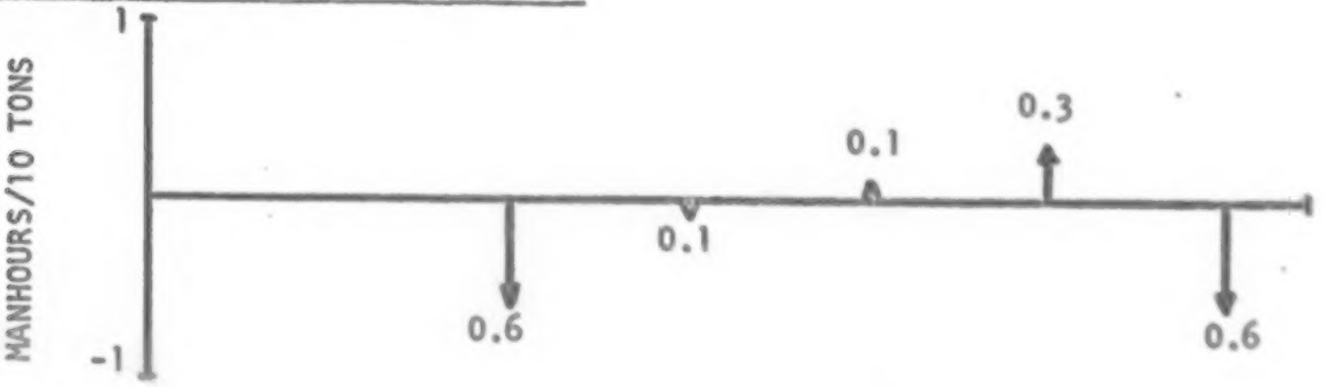


TABLE 11 [*]

Statistical test of the difference between technological levels in annealing steel strip.

Manhour data, Firms C and D

Source of Variance	D.F.	V.R.	Significance Level
Between skill level	2	228.57	$P<0.001$
Between technologies	1	30.00	$P<0.025$
Between firms	1	5.71	
SL x T	2	21.40	$P<0.05$
SL x F	2	4.30	
T x F	1	0.0	

[*] for more detailed data see Appendix II.

TABLE 12: ESTIMATED REQUIRED HIGH SCHOOL EDUCATION, ANNEALING, FIRMS C & D

High School Education (years)	Average Manhours Per 10 Tons			Average Manhours as % of Total for each Technology Level		
	TL 1	TL 2	Change	TL 1	TL 2	Change
2.1-4.0	0.0	0.3	+0.3	0.0	19.1	+19.1
0.1-2.0	0.8	0.3	-0.5	35.2	19.1	-16.1
0	1.5	1.0	-0.5	64.8	61.8	-3.0

MEAN EDUCATIONAL LEVEL (years of high school)	TL 1	TL 2
	0.4	1.8

TABLE 13: ESTIMATED REQUIRED ON-THE-JOB EXPERIENCE, ANNEALING, FIRMS C & D

On-the-job Experience (Months)	Average Manhours Per 10 Tons			Average Manhours as % of Total for each Technology Level		
	TL 1	TL 2	Change	TL 1	TL 2	Change
25-30	0.2	0.0	-0.2	7.4	0.0	-7.4
19-24	0.1	0.3	+0.2	5.2	19.1	+11.9
13-18	0.2	0.3	+0.1	9.5	19.1	+9.6
7-12	0.6	0.6	0.0	24.2	38.2	+14.0
3-6	1.2	0.4	-0.8	51.5	23.7	-27.8
0-2	0.1	0.0	-0.1	2.2	0.0	-2.2

MEAN LENGTH OF EXPERIENCE (months)	TL 1	TL 2
	9.3	11.8

As regards on-the-job experience, the pattern changes more markedly. Not only has the mean requirement for on-the-job experience risen from something over 9 months to nearly 12 months, but in addition more than three-quarters of the manhours going into the continuous annealing process necessitated a backing of over 7 months experience, while more than half the manhours on the older process require 6 months' experience or less.

The significant upward shift in skill level measured by job evaluation and associated with technological change found above thus seems to be a composite effect of a) increased educational requirements of some of the key operators and b) increased requirements for on-the-job experience of the bulk of the labor-force running the newer process. Prolonged experience on the process itself would therefore seem to be an insufficient qualification for an operator seeking promotion to the top jobs; it may be surmised that his lack of formal education would disable a worker with little education from acquiring conceptual notions sufficiently structured to warrant his being entrusted with controlling the process as a whole.

4.4 Sheet and continuous coating of steel strip (Studies C3,C4,D3,D4)

Galvanizing and tinplating are both processes for protecting sheet steel from corrosion by depositing a thin layer of another metal on the surface; in galvanizing the second metal is metallic zinc and in tinplating metallic tin. The layers are deposited either directly (hot-dip process) or by electrochemical action from a solution of a salt of the metal to be deposited (electrolytic tinning process).

Although the older methods of galvanizing or tinplating steel sheets by dipping them into a bath of molten metal (hot-dip processes) were extensively mechanized, there were three factors which made their ultimate displacement inevitable. Cutting up steel strip into plates before coating entails much more handling than cutting it up afterwards; the need for repeated handling of decks of pre-cut sheets and for feeding them individually into the coating equipment is time consuming and requires extra labor; and the speed at which the lines can be run without excessive spoilage is relatively low.

In hot-dip galvanizing (study C3), the steel strip was uncoiled, cut, inspected, sorted and piled into decks, these decks were then transported to the feeding table of the galvanizing line where an operator lifted each sheet with tongs and fed it between rollers, another operator wiped the trailing edge after emergence from the bath, two operators lifted the sheets off at the end of the line, turned them for inspection purposes, and restacked them. Similarly in the older method of hot-dip tinplating (study D3), decks of sheets were transported from the cut-up line to the start of the tinning line, although here the operator merely had to shunt palletized decks to a mechanical feeding device, while another operator inspected sheets as they emerged at the exit end of line (see Figures 12 and 14 for process-charts).

Many of these handling operations dropped out or were telescoped in the continuous processes, which on the other hand required more personnel engaged on controlling and regulating the consecutive stages of processing. But the higher running speed of the continuous lines, which is many times that of the older lines in both coating processes, ensures more intensive labor utilization.

The continuous lines represent a very considerable engineering achievement, bearing in mind that the relatively thin and brittle strip is liable to swing sideways and break unless perfectly balanced and evenly tensioned at all points; that it must be fed into the bath of molten metal at rates lying within narrow tolerance limits; and that malfunctions of the processing equipment at any stage are bound to lead to high waste in terms of material spoiled and time spent restarting the process. Because of the very high speeds involved, most of the regulating, balancing and corrective functions must necessarily be built into the equipment. In addition the activities of the process crew must be very highly coordinated. Thus the new lines are technologically far ahead of their precursors. Neither the abbreviated process charts given here (Figures 13,15) nor the more detailed diagrams and illustrations in Appendix III do full justice to the extent of the technological advance that has been achieved.

Changes in skill requirements (Tables 14,15; Figures 16,17)

The differing patterns of change evident from the profiles for the two coating processes were associated with technological differences between galvanizing and tinning at technology level 1, but the distributions at technology level 2 were remarkably similar. The reductions in total per-unit labor requirements were also of the same order and very substantial, 69.5% for galvanizing, 73.4% for tinning.

Lower and medium skill-level manhours were greatly reduced in both coating processes, at the upper skill levels continuous galvanizing showed an increase but tinplating a decrease; this difference seems to have been due to the fact that the operation of the older tinplating process was more critical and difficult requiring relatively higher grade labor than the historically older and relatively crude galvanizing process.

In galvanizing the mean skill level rose by as much as 1.2 points (50%) while in tinplating there was a small drop of 0.1 points (3%). Using the consistency between firms as a measure of reliability, the change in skill level was tested for statistical significance by analysis of variance, the results of which are summarized in Table 16.

Again the "between firms" variance ratio was not statistically significant, indicating comparability, while the skill-level by technology-level interaction term was significant at the 25% level, which makes it clear that the observed increase in skill level from the older to the newer technology could not have been due to chance. Though this may not be questioned for galvanizing, the data for tinplating appear to contradict the calculated results. The explanation is that, since the analysis of variance pools the data for the two firms, the upward shift in galvanizing was sufficiently large, taken together with the small change in tinplating,

FIGURE 12

PROCESS C3: SHEET GALVANIZING

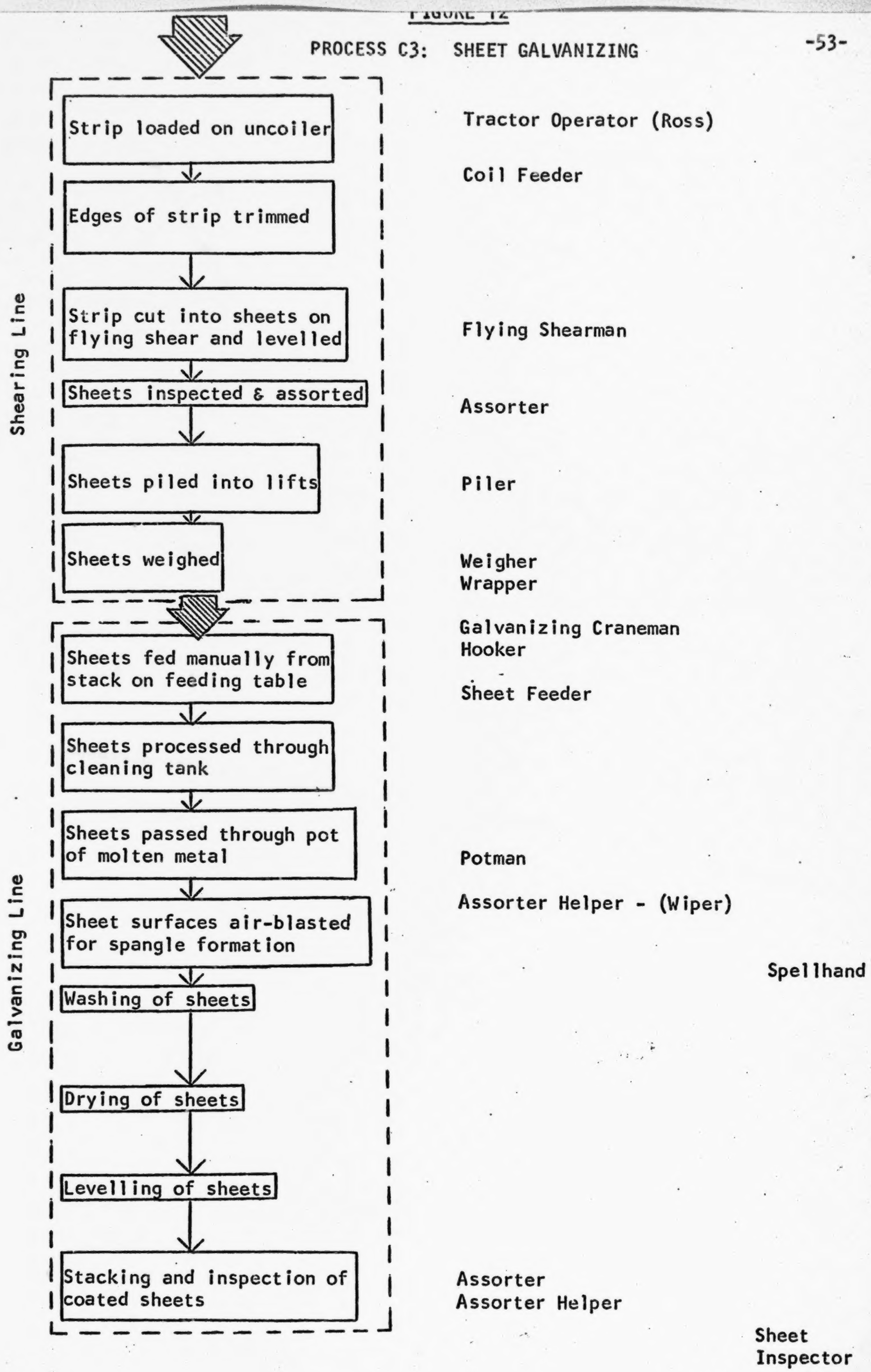
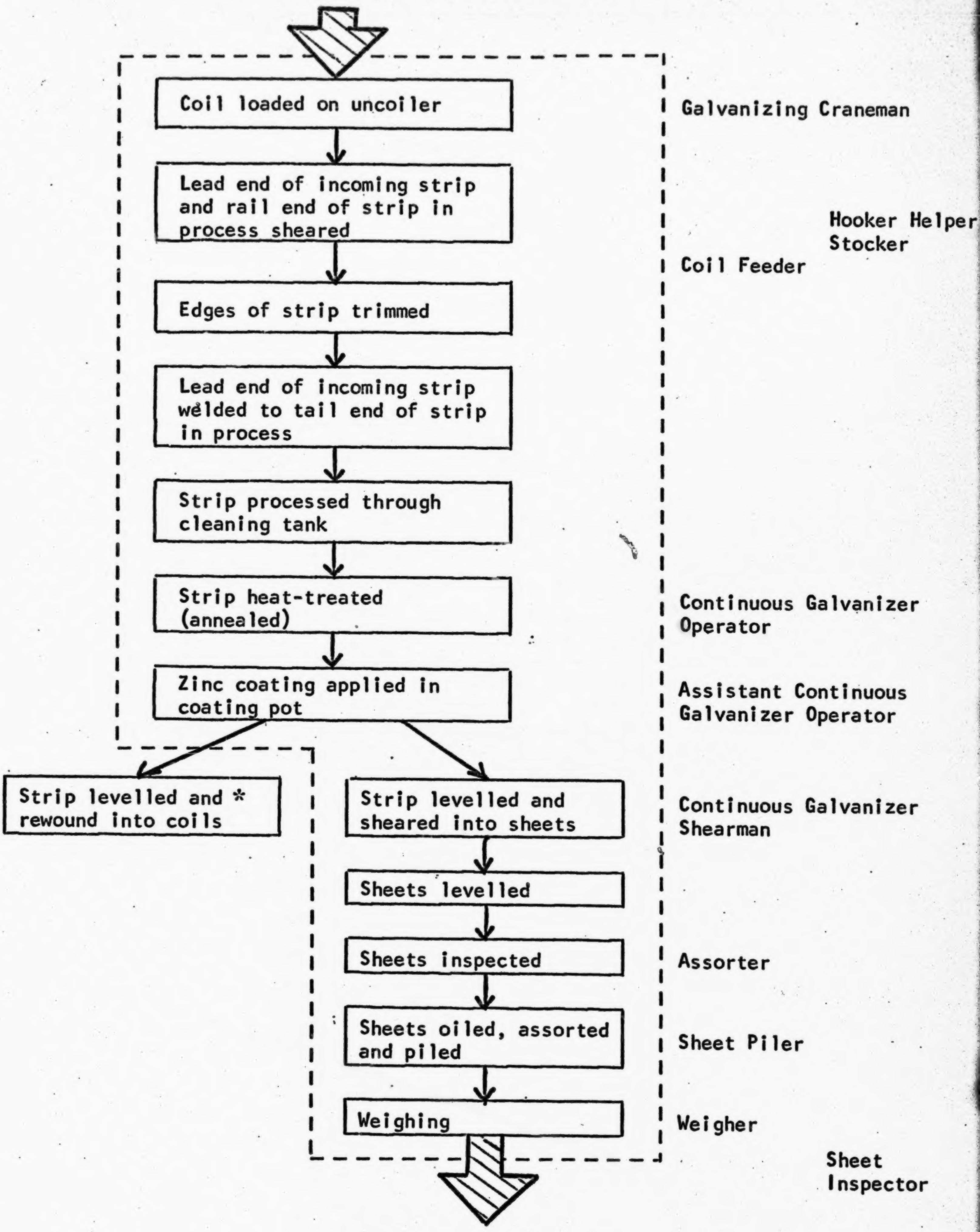

Shearing Line
Strip loaded on uncoiler
Tractor Operator (Ross)
Coil Feeder
Edges of strip trimmed
Strip cut into sheets on flying shear and levelled
Flying Shearman
Sheets inspected & assorted
Assorter
Sheets piled into lifts
Piler
Sheets weighed
Weigher
Wrapper
Galvanizing Line
Galvanizing Craneman
Hooker
Sheets fed manually from stack on feeding table
Sheet Feeder
Sheets processed through cleaning tank
Sheets passed through pot of molten metal
Potman
Assorter Helper - (Wiper)
Sheet surfaces air-blasted for spangle formation
Spellhand
Washing of sheets
Drying of sheets
Levelling of sheets
Stacking and inspection of coated sheets
Assorter
Assorter Helper
Sheet Inspector

FIGURE 13

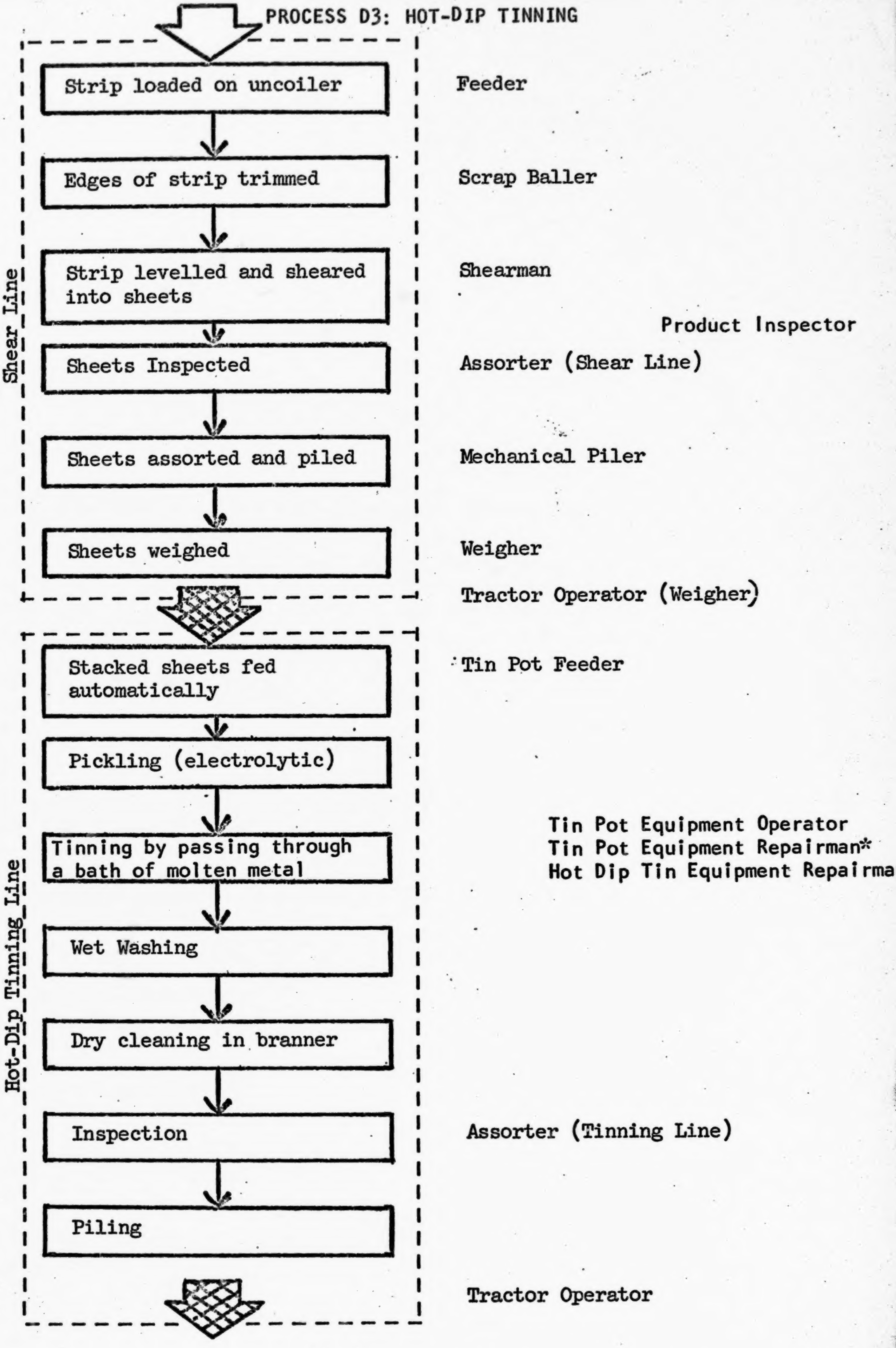
PROCESS C4: CONTINUOUS GALVANIZING


Coil loaded on uncoiler
Galvanizing Craneman
Lead end of incoming strip and rail end of strip in process sheared
Hooker Helper
Stocker
Coil Feeder
Edges of strip trimmed
Lead end of incoming strip welded to tail end of strip in process
Strip processed through cleaning tank
Strip heat-treated (annealed)
Continuous Galvanizer Operator
Zinc coating applied in coating pot
Assistant Continuous Galvanizer Operator
Strip levelled and rewound into coils *
Strip levelled and sheared into sheets
Continuous Galvanizer Shearman
Sheets levelled
Sheets inspected
Assorter
Sheets oiled, assorted and piled
Sheet Piler
Weighing
Weigher
Sheet Inspector

* Since only sheets can be produced on the older processes, the personnel and skill levels involved in this operation have not been indicated in the data.

FIGURE 14

PROCESS D3: HOT-DIP TINNING


Shear Line
Strip loaded on uncoiler
Feeder
Edges of strip trimmed
Scrap Baller
Strip levelled and sheared into sheets
Shearman
Product Inspector
Sheets Inspected
Assorter (Shear Line)
Sheets assorted and piled
Mechanical Piler
Sheets weighed
Weigher
Tractor Operator (Weigher)
Hot-Dip Tinning Line
Stacked sheets fed automatically
Tin Pot Feeder
Pickling (electrolytic)
Tinning by passing through a bath of molten metal
Tin Pot Equipment Operator
Tin Pot Equipment Repairman*
Hot Dip Tin Equipment Repairma
Wet Washing
Dry cleaning in branner
Inspection
Assorter (Tinning Line)
Piling
Tractor Operator

*Members of work crew, not maintenanc

FIGURE 15

PROCESS D4: CONTINUOUS ELECTROLYTIC TINNING

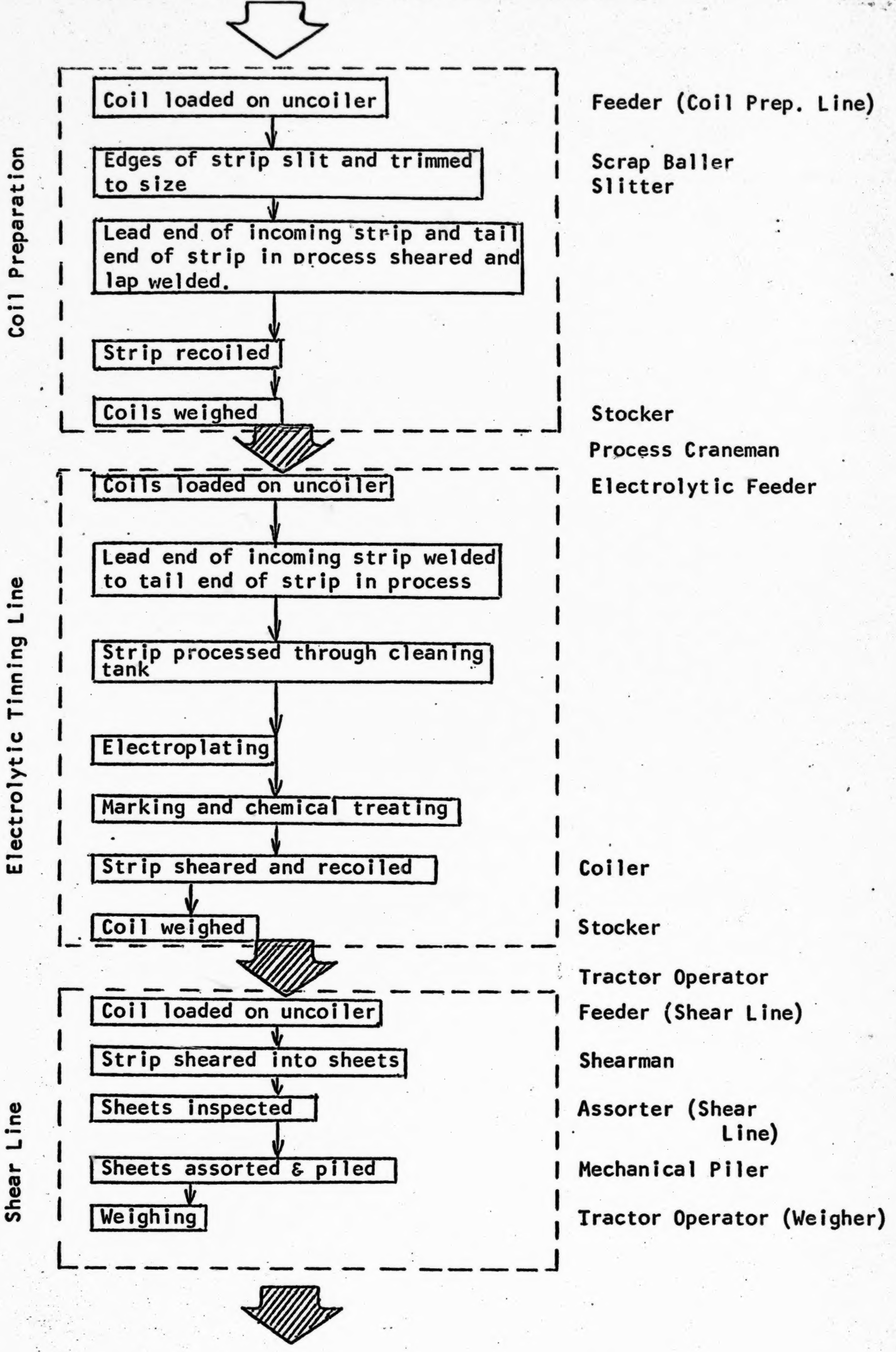

Coil Preparation
Coil loaded on uncoiler
Feeder (Coil Prep. Line)
Edges of strip slit and trimmed to size
Scrap Baller
Slitter
Lead end of incoming strip and tail end of strip in process sheared and lap welded.
Strip recoiled
Coils weighed
Stocker
Process Craneman
Electrolytic Tinning Line
Coils loaded on uncoiler
Electrolytic Feeder
Lead end of incoming strip welded to tail end of strip in process
Strip processed through cleaning tank
Electroplating
Marking and chemical treating
Strip sheared and recoiled
Coiler
Coil weighed
Stocker
Tractor Operator
Shear Line
Coil loaded on uncoiler
Feeder (Shear Line)
Strip sheared into sheets
Shearman
Sheets inspected
Assorter (Shear Line)
Sheets assorted & piled
Mechanical Piler
Weighing
Tractor Operator (Weigher)

TABLE 14

COMPARATIVE SKILL DISTRIBUTIONS - C3 and C4

Organization: Steelworks C

Process: Coating Product unit: 10 tons

Technology (Level 1): Sheet Galvanizing (Hot-Dip)

Technology (Level 2): Continuous Strip Galvanizing

Source of Data: Direct Observation

Period: Fall 1965

1		2	3	4	5	6	7	8	9	10	11
SKILL LEVEL		SKILL POINT RANGE	MANHOURS PER 10 TONS			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
			TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CH
High	6	5.5-6.4	0.0	0.4	+0.4	0.0	10.2	+10.2	-	1	+1
	5	4.5-5.4	0.0	0.4	+0.4	0.0	10.2	+10.2	-	1	+1
	4	3.5-4.4	1.7	1.0	-0.7	13.3	25.6	+12.3	4	3	-1
Medium	3	2.5-3.4	4.6	1.6	-3.0	35.9	41.0	+ 5.1	5	4	-1
	2	1.5-2.4	5.1	0.4	-4.7	39.8	10.3	-29.5	5	1	-4
Low	1	0.5-1.4	1.4	0.1	-1.3	10.9	2.6	- 8.3	1	1	0
	0	0.0-0.4	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
		TOTALS	12.8	3.9	-8.9	100.0	100.0	0.0	15	11	-4
		NET % MANHOUR CHANGE -69.5%									

	Mean Skill Level	Standard Deviation
Technology (Level 1)	2.4	1.0
Technology (Level 2)	3.6	1.3
Change	+1.2	

TABLE 15

COMPARATIVE SKILL DISTRIBUTIONS - D3 and D4

Organization: Steelworks D

Process: Coating Product unit: 100 base boxes

Technology (Level 1): Hot-Dip Tinning

Technology (Level 2): Continuous Electrolytic Tinning

Source of Data: Direct Observation

Period: Fall 1965

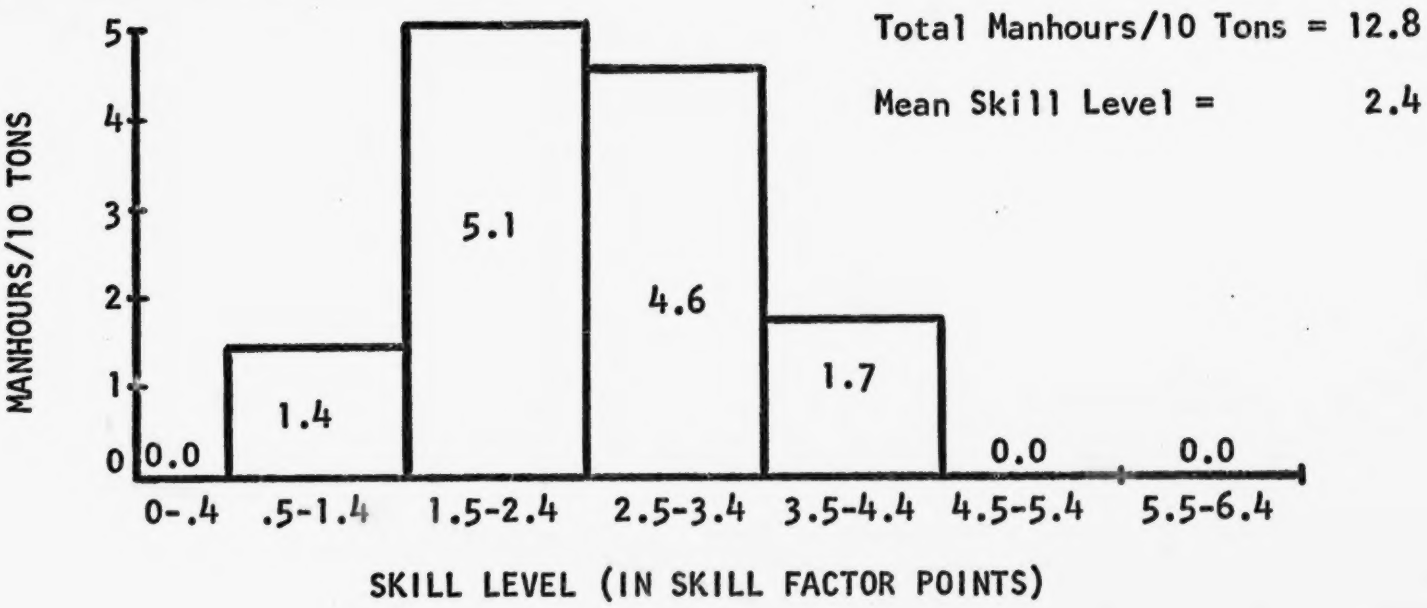
1		2	3	4	5	6	7	8	9	10	11
SKILL LEVEL		SKILL POINT RANGE	MANHOURS PER 100 -BASEBOXES			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
			TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG.
High	6	5.5-6.4	1.7	0.3	-1.4	15.6	10.3	-5.3	2	1	-1
	5	4.5-5.4	1.2	0.3	-0.9	11.0	10.3	-0.7	2	1	-1
	4	3.5-4.4	0.2	0.6	+0.4	1.8	20.7	+18.9	1	3	+2
Medium	3	2.5-3.4	6.9	1.0	- 5.9	63.3	34.5	-28.8	4	6	+2
	2	1.5-2.4	0.7	0.6	- 0.1	6.4	20.7	+14.3	3	4	+1
Low	1	0.5-1.4	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	0	0.0-0.4	0.2	0.1	- 0.1	1.8	3.4	+ 1.6	1	1	0
		TOTALS	10.9	2.9	- 8.0	100.0	100.0	0.0	13	16	+5
		NET % MANHOUR CHANGE			-73.4%						

	Mean Skill Level	Standard Deviation
Technology (Level 1)	3.3	1.5
Technology (Level 2)	3.2	1.3
Change	-0.1	

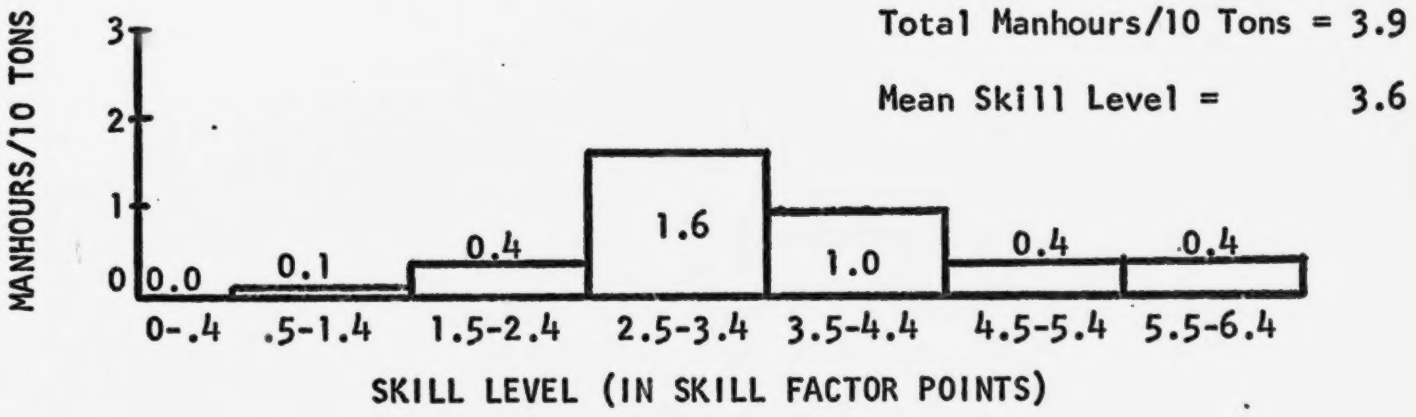
FIGURE 16

COMPARATIVE SKILL PROFILES - C3 and C4

SHEET GALVANIZING (HOT DIP)



CONTINUOUS STRIP GALVANIZING



CHANGES - OLD TO NEW TECHNOLOGY

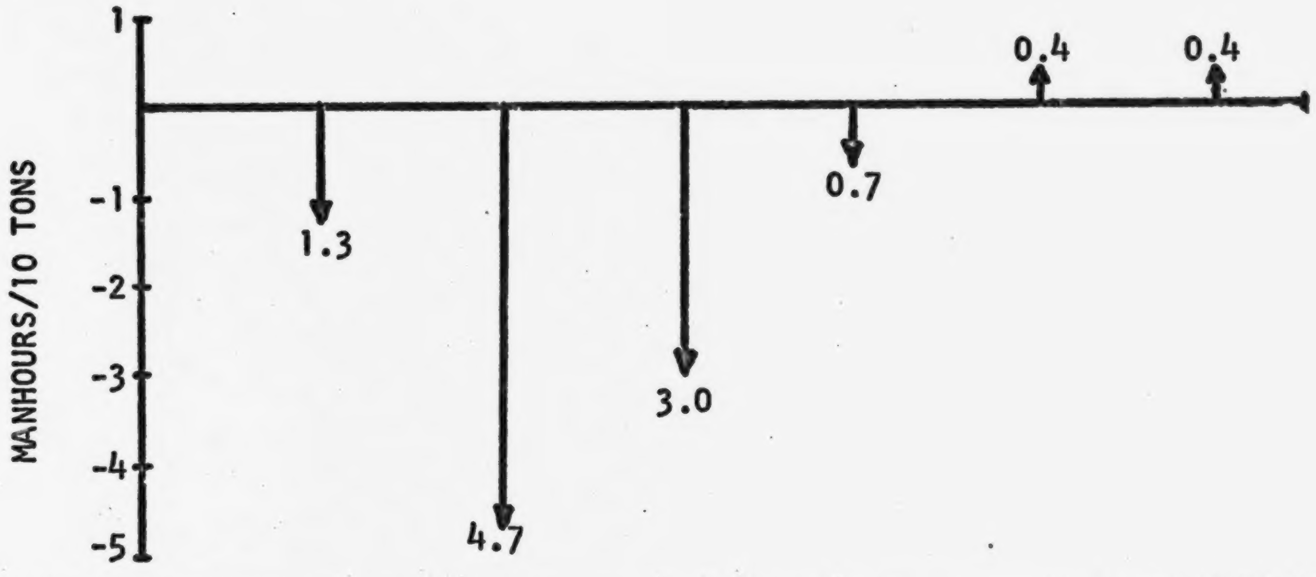
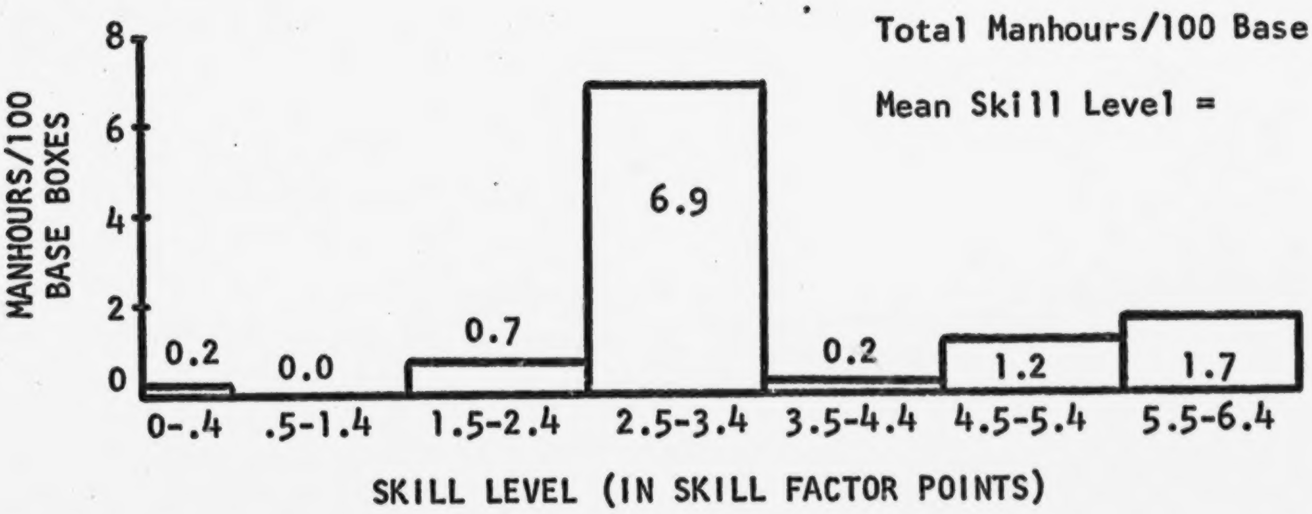


FIGURE 17

COMPARATIVE SKILL PROFILES - D3 and D4

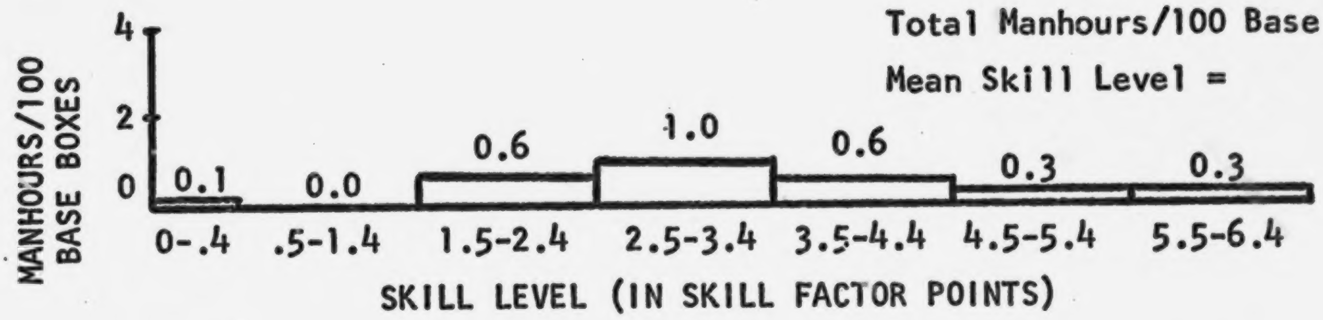
HOT DIP TINNING



Total Manhours/100 Base Boxes = 10.

Mean Skill Level = 3.

CONTINUOUS ELECTROLYTIC TINNING



Total Manhours/100 Base Boxes = 2.

Mean Skill Level = 3.

CHANGES - OLD TO NEW TECHNOLOGY

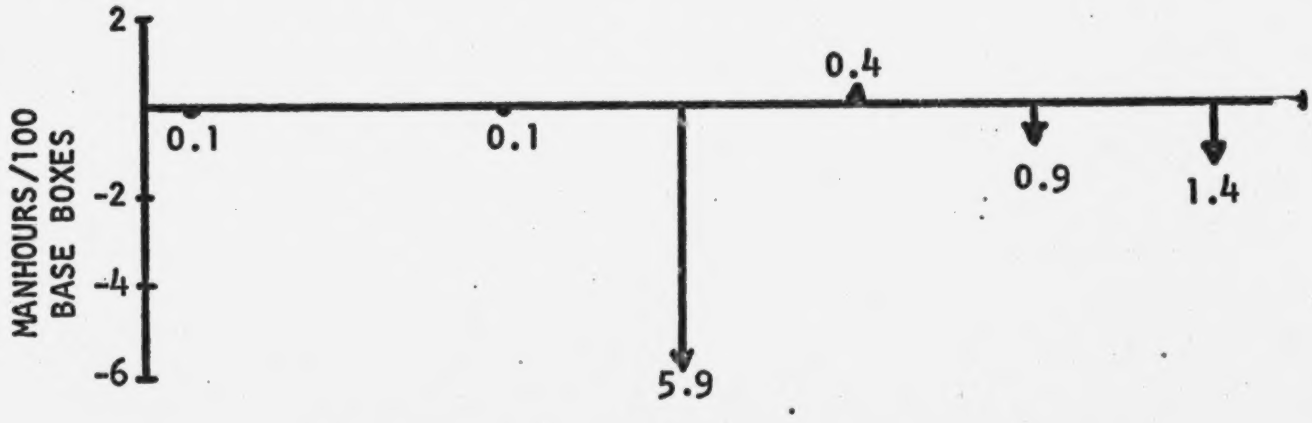


TABLE 16

Statistical test of the difference between technological levels in galvanizing and tinning processes.

Source of Variance	D.F.	V.R.	Significance Level
Between skill levels	2	33.1	$P < 0.01$
Between technologies	1	33.5	$P < 0.01$
Between firms	1	0.9	
SL x T	2	16.2	$P < 0.025$
SL x F	2	0.9	
T x F	1	0.0	

More detailed data see Appendix III.

to overcome the variation between firms. It is again important to emphasize that the main factor contributing to changes in skill level were the large decreases in requirement at the medium skill level, rather than any absolute increase at higher levels.

Changes in skill-content

The small drop in number of job-types in galvanizing was almost precisely offset by a small increase in tinning, leaving no net change. Apparently then the range of skill-content is unaffected by technology.

Changes in educational and on-the-job experience requirements

The data given in Tables 17 and 18, summarizing the educational and on-the-job experience requirements of the older and newer coating processes, are based on detailed estimates given in Appendix III, averaged over the coating processes studied in firms C and D.

The pattern of changes revealed is broadly similar to that for the annealing processes. There was some rise in the mean education level, reflecting relatively increased requirements for operators with up to 2 years of high school and 2-4 years of high school (last three columns of Table 17) in the newer technologies. However most of the tasks in both older and newer processes apparently needed no high school education previous to on-the-job experience.

Requirements for on-the-job experience have risen substantially. The mean length of experience increased from some 7 to 11½ months and 60% of the manhours on the new process needed 7 months or more, where 67% of the manhours on the older process required 6 months or less.

This again seems to be a case where a few of the key operations in the new process require operators with considerably more basic education and longer experience than in the older one. Most of the other tasks require more experience but no more education.

As with annealing, the lack of a minimal high-school education would appear to act as a bar preventing promotion to the senior operating jobs on the new process.

Taken all together, the two sets of steel industry comparisons, which both cover an advance from batch to continuous-flow production in processing strip metal, show a consistent pattern of change in skill-requirements, job-contents, educational and job-experience requirements.

4.5 Machining of complex parts on conventional and numerically-controlled machine-tools (Studies E1,E2,F1,F2).

The final series of studies examined a major technological change is the old-established method of shaping metal parts by the use of power-driven cutting tools, a process generically known as "machining". The change was from manual to automatic control of the detailed sequence of cutting actions used in milling, drilling, turning, boring and other like operations.

In the conventional method, which should be familiar enough to readers not to require detailed description, both the overall sequence of machining operations and the details of clamping-positions, feeds, speeds and cuts are preplanned for each part, but the machinist or machine operator uses his discretion as to the detailed manner of achieving the dimensions specified on the customer's blueprint. Great care is required since removing slightly too much metal can cause an expensive casting or semifinished part to be discarded as useless scrap.

In numerical-control machining the degree of preplanning has been extended to include the complete sequence of cutting actions, and no discretion whatever is left to the machine operator. This is achieved by providing a complete list of instructions in machine-readable form on punched-paper or magnetic tape for execution by automatic devices controlling the various motions of the part and cutting tool. There has been no change in the mechanical cutting action itself, nor in the overall motion path, and only the mode of feeding information to the powered cutting system has been mechanized.

In n/c machining the data-tape is itself regarded as a "tool"; it is prepared by staff specialists known as parts-programmers during the planning and tooling phase preceding production of each new part ordered, and becomes part of the "tool-kit" supplied to the operator. During the "set-up" operation for each batch of parts the operator assembles jigs, fixtures and cutting tools in the conventional manner, and then loads the tape into the tape-reader and sets in a positional reference relative to a datum point on part or fixture.

After assembling and clamping each successive part in the batch to its prepared position in the fixture, he starts the tape, and under normal circumstances no further action is needed until the machining cycle is completed, when he reloads another part, runs the tape back and restarts the cycle.

The complete production of a part often includes de-burring and polishing, neither of which are done by numerical control; there can be little doubt, however, that these operations will ultimately be eliminated by more precise control of surface finish or otherwise mechanized. This development may coincide with, or even be preceded by, the complete or near complete preparation of programmed tapes by computer directly from blueprints. (For a fuller account of the technology see Appendix IV).

Changes in skill requirements

The technological change from conventional to numerically controlled machining is reflected in reduced manhour and skill requirements as the tables (19,20) and profile diagrams (Figures 18,19) show. In one firm (E), there was a reduction of 29% in manhours per part, deriving from a complete elimination of manhours at the highest skill level together with small reductions at lower levels. In the other firm (F) a decline of 37% in the manhour requirement was associated with a more than three-quarter reduction at the highest skill level and slight reductions at several other levels. (These results were obtained by averaging over a selected set of parts produced; see Appendix IV).

TABLE 17: ESTIMATED REQUIRED HIGH SCHOOL EDUCATION, COATING, FIRMS C & D

High School Education (years)	Average Manhours Per 10 Tons or 100 Baseboxes			Average Manhours as % of Total for each Technology Level		
	TL 1	TL 2	Change	TL 1	TL 2	Change
2.1-4.0	0.0	0.3	+0.3	0.0	9.5	+9.5
0.1-2.0	1.4	0.8	-0.6	11.6	22.4	+10.8
0	10.5	2.3	-8.2	88.4	68.1	-20.3

MEAN EDUCATIONAL LEVEL (years of high school)	TL 1	TL 2
	0.1	0.5

TABLE 18: ESTIMATED REQUIRED ON-THE-JOB EXPERIENCE, COATING, FIRMS C & D

On-the-job Experience (Months)	Average Manhours Per 10 Tons or 100 Baseboxes			Average Manhours as % of Total for each Technology Level		
	TL 1	TL 2	Change	TL 1	TL 2	Change
25-30	0.0	0.3	+0.3	0.0	9.5	+9.5
19-24	0.9	0.3	-0.6	7.8	10.1	+2.3
13-18	0.9	0.8	-0.1	7.2	23.1	+15.9
7-12	2.1	0.6	-1.5	18.0	16.3	-1.7
3-6	5.9	1.2	-4.7	49.6	34.7	-4.9
0-2	2.1	0.2	-1.9	17.5	6.2	-11.3

MEAN LENGTH OF EXPERIENCE (months)	TL 1	TL 2
	6.9	11.5

TABLE 19

COMPARATIVE SKILL DISTRIBUTIONS - E1 and E2

Organization: Aerospace Firm E

Product Unit: one part

Process: Machining Aircraft Components Nos. 141 and 891*

Technology (Level 1): Conventional Machining

Technology (Level 2): Numerically Controlled Machining

Source of Data: Direct Observation

Period: Fall 1965

1		2	3	4	5	6	7	8	9	10	11
SKILL LEVEL		SKILL POINT RANGE	AVERAGE MANHOURS PER PART			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
			TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG
High	6										
	5	640-699	0.3	0.0	-0.3	7.9	0.0	-7.9	1	-	-1
	4	580-639	2.1	1.9	-0.2	55.3	70.4	+15.1	1	1	0
Medium	3	520-579	0.7	0.3	-0.4	18.4	11.1	-7.3	3	3	0
	2	460-519	0.4	0.3	-0.1	10.5	11.1	+0.6	1	1	0
Low	1	400-459	0.3	0.0	- 0.3	7.9	0.0	-7.9	2	1	-1
	0	340-399	0.0	0.2	+0.2	0.0	7.4	+ 7.4	-	1	+1
		TOTALS	3.8	2.7	-1.1	100.0	100.0	0.0	8	7	-1
		NET % MANHOUR CHANGE -28.9%									

	Mean Skill Level	Standard Deviation
Technology (Level 1)	585.4	56.9
Technology (Level 2)	579.2	63.6
Change	-6.2	

*for comparative skill distributions for the two parts individually see Appendix IV.

TABLE 20

COMPARATIVE SKILL DISTRIBUTIONS - F1 and F2

Organization: Aerospace Firm F Product Unit: one part

Process: Machining Aircraft Components Nos: 452, 884, 549, 389, 601 and 398*

Technology (Level 1): Conventional Machining

Technology (Level 2): Numerically Controlled Machining

Source of Data: Direct Observation

Period: Fall 1965

1		2	3	4	5	6	7	8	9	10	11
SKILL LEVEL		SKILL POINT RANGE	AVERAGE MANHOURS PER PART			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
			TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG
High	6										
	5	640-699	1.8	0.3	-1.5	47.4	14.3	-33.1	1	1	0
	4	580-639	1.2	1.4	+0.2	31.6	66.7	+35.1	1	1	0
Medium	3	520-579	0.3	0.0	-0.3	7.9	0.0	-7.9	1	-	-1
	2	460-519	0.4	0.2	-0.2	10.5	9.5	- 1.0	1	1	0
Low	1	400-459	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	0	340-399	0.1	0.2	+0.1	2.6	9.5	+ 6.9	1	1	0
		TOTALS	3.8	2.1	-1.7	100.0	100.0	0.0	5	4	-1
		NET % MANHOUR CHANGE -44.7%									

	Mean Skill Level	Standard Deviation
Technology (Level 1)	623.8	60.2
Technology (Level 2)	595.4	69.8
Change	-28.4	

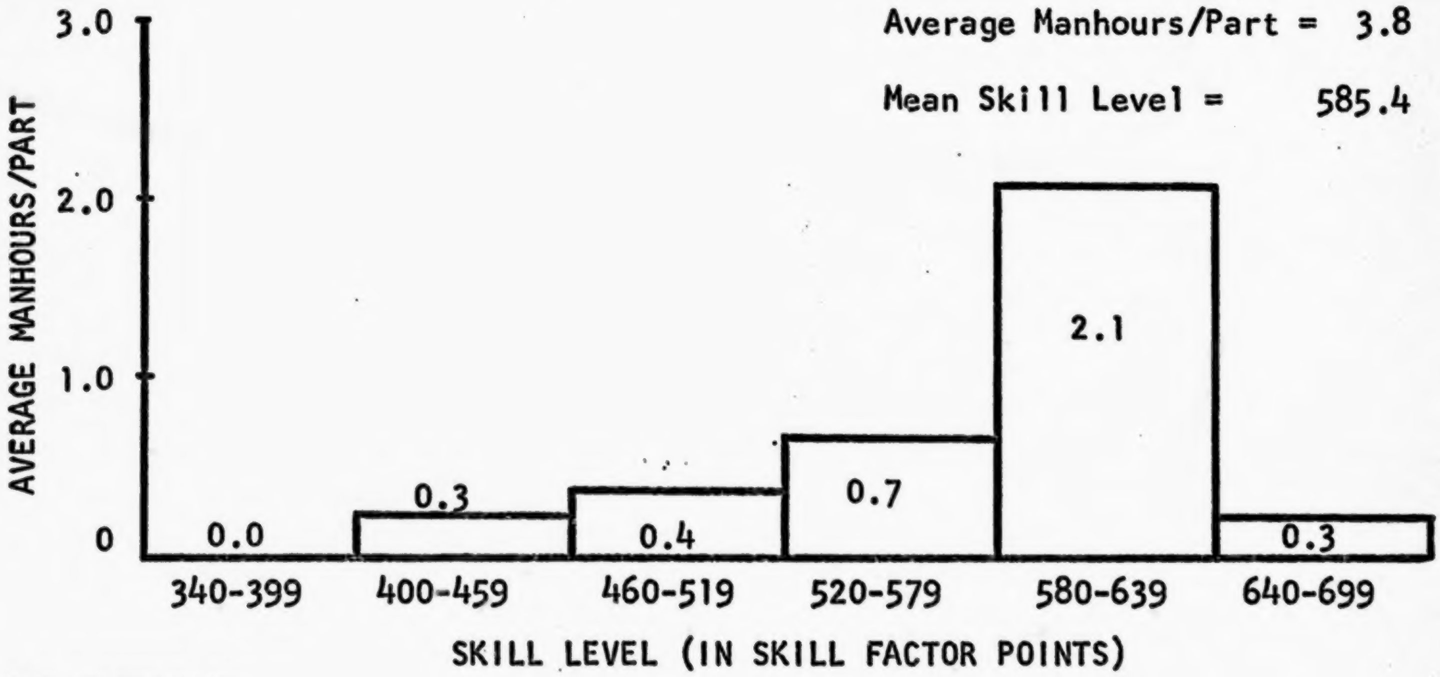
---

*for comparative skill distributions for the six parts individually see Appendix IV.

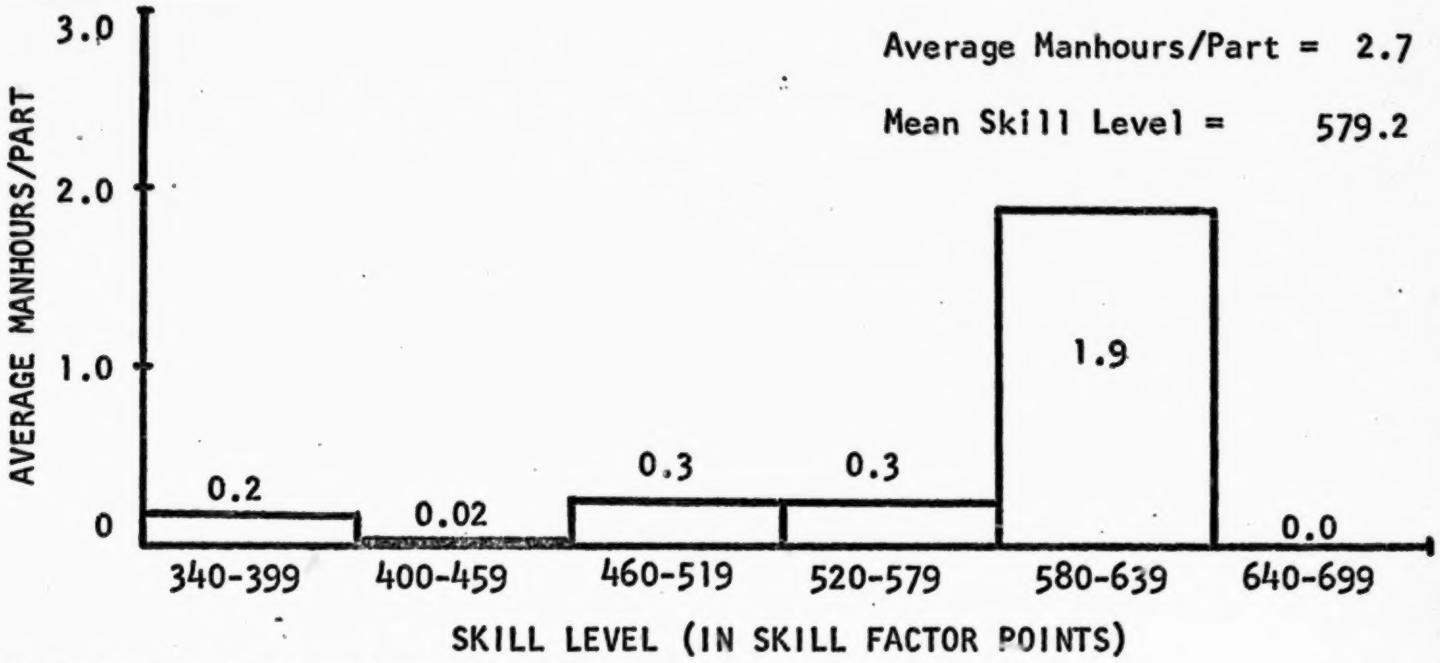
FIGURE 18

COMPARATIVE SKILL PROFILES - E1 and E2
(Individual skill profiles for parts
141 and 891 in Appendix IV)

CONVENTIONAL MACHINING



N/C MACHINING



CHANGES - OLD TO NEW TECHNOLOGY

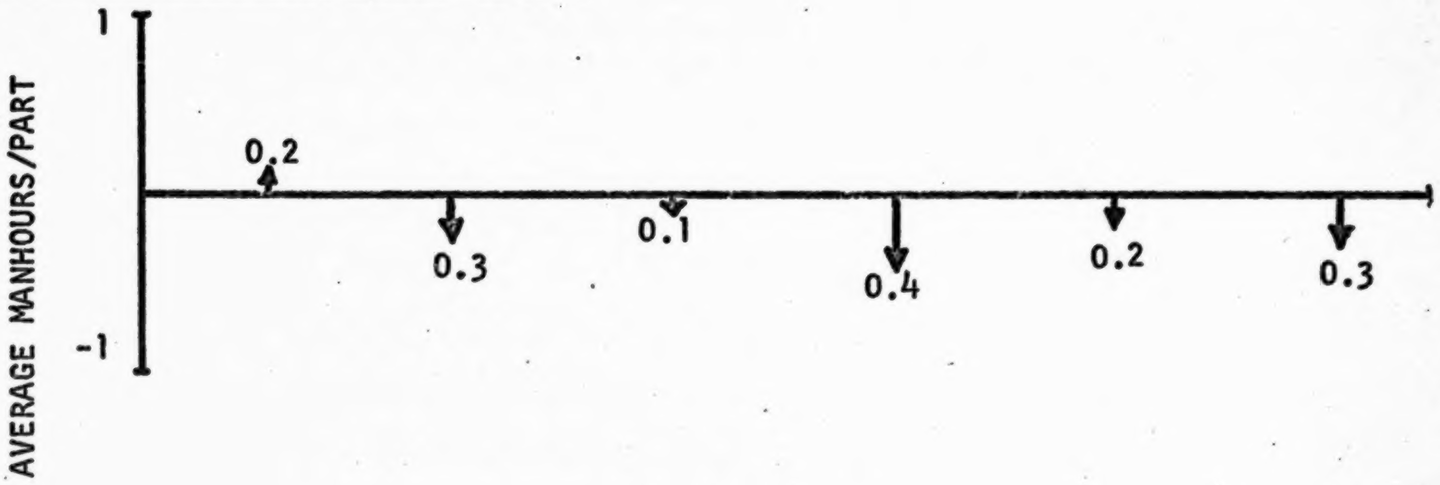
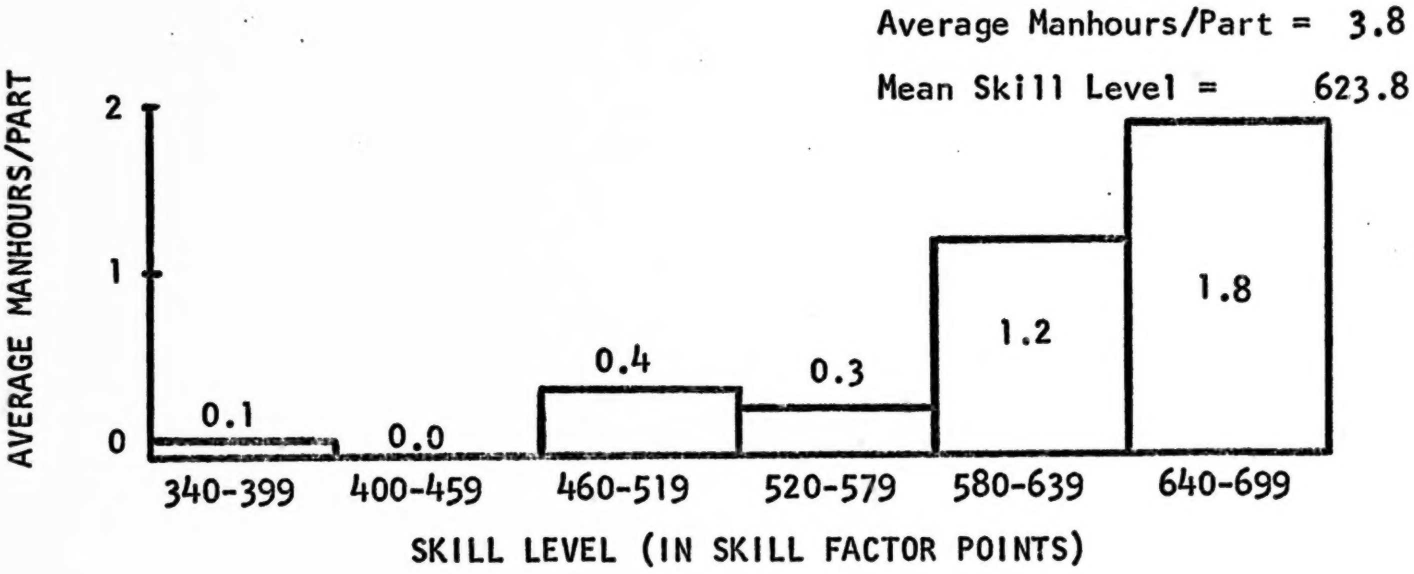


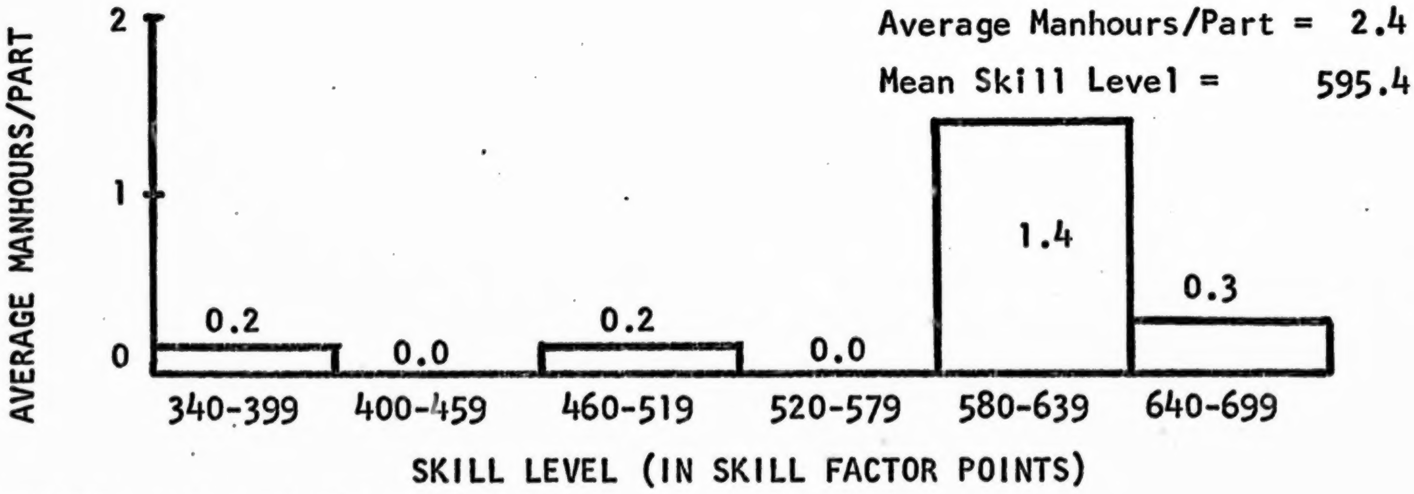
FIGURE 19

COMPARATIVE SKILL PROFILES - F1 and F2
(Individual skill profiles for parts
452,884,549,389,601 and 398 in App.IV)

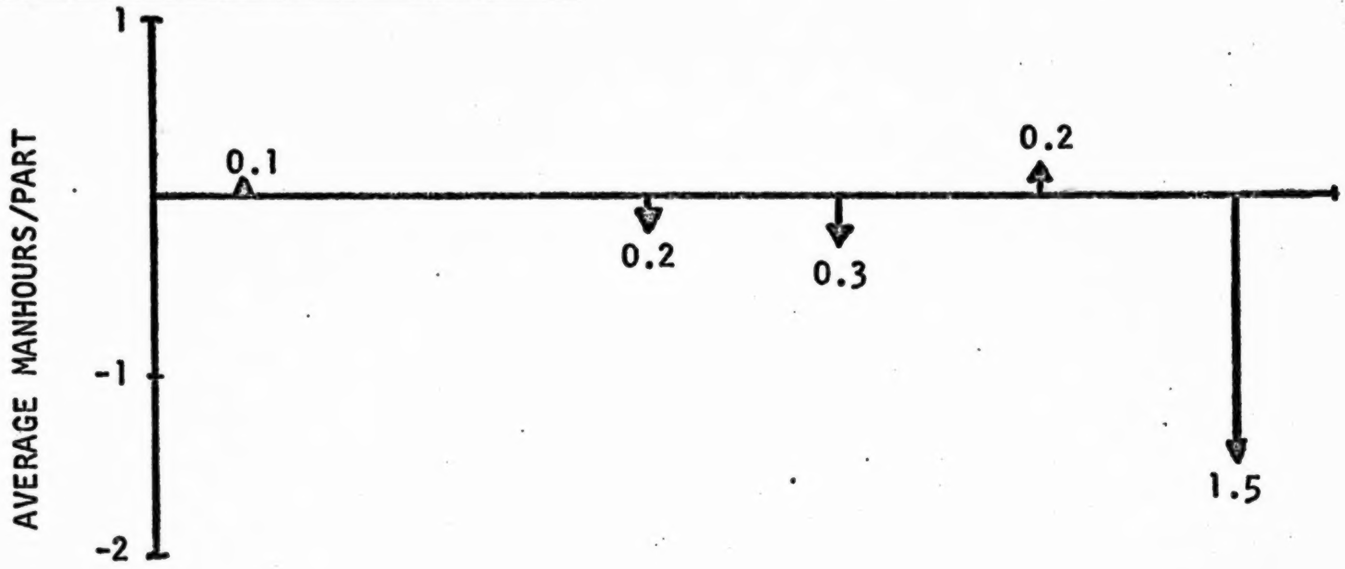
CONVENTIONAL MACHINING


Average Manhours/Part = 3.8
Mean Skill Level = 623.8

N/C MACHINING


Average Manhours/Part = 2.4
Mean Skill Level = 595.4

CHANGES - OLD TO NEW TECHNOLOGY



The drop in skill level was tested for statistical significance by comparing the manhour inputs at 3 skill levels (lower, medium, higher) and at 2 levels of technology, aggregating the data from both firms. The outcome of the analysis of variance is given in Table 21. The interaction between skill-level and technology-level was significant beyond the 1% probability level, indicating that the observed change in skill-distribution associated with change in technology in the two firms taken together are unlikely to have arisen by chance.

A more detailed presentation of the analysis of variance and data from which it was derived are given in Appendix IV.

Changes in skill-content

The number of job types in both firms remained the same, indicating broadly the same pattern of skill-content in both technologies.

Changes in educational and on-the-job experience requirements

Averaged estimates of educational and experience requirements are given in Tables 22 and 23; for more detailed data reference should be made to Appendix IV.

By contrast with the three previous comparisons, the change from conventional to numerically controlled machining technology is associated with a reduction both in estimated educational requirements and in required job-experience. This finding is consistent with the small but statistically significant decrease in mean skill-level which occurred in both firms (Tables 19,20).

The mean education requirement was reduced from 3 years of high schooling to 2 years. As will be evident from the last three columns of Table 22, the number of manhours supplied by personnel with more than 2 years of high schooling went down from nearly 100% to about 67%, and 33% of the manhours going into N/C operation require no high schooling at all.

The requirements for on-the-job experience have also been markedly reduced. This is not quite as apparent from the decrease in the mean value from 33 months to 28 months, as from the shift in the percentage distributions. Whereas almost 40% of the manhours on conventional machining require from 37-48 months of experience, over 90% of the N/C manhours require only 1-36 months.

Both Tables 22 and 23 thus confirm the impression gained from direct observation that most of the more complex judgments and decisions have already been taken over by the machine, leaving the man with a much reduced decision-load most of which consists in relatively routine tasks and operations.

§§ CHAPTER

5. CONCLUSIONS ON PRODUCTIVITY AND SKILL REQUIREMENTS IN RELATION TO TECHNOLOGICAL CHANGE

In this chapter the results from the ten pairs of studies are considered as a whole for the light they shed on the problems and hypotheses stated in

Chapter 1 regarding the impact of technological change on the general level of skill and education required in the direct production workforce. For convenience the results are summarized in Tables 24 and 25.

It will be recalled that, following the work of J.R. Bright and others, the main hypothesis to be tested was that high levels of automation and mechanization tend to diminish rather than increase the average level of skill required of the work force. If observed, this shift in skill-level would be secondary to the increase in overall labor-productivity and hence reduction in production cost that is the primary objective for which managements invest in newer, more mechanized means of production. Productivity changes will therefore be discussed first.

5.1 Productivity

All five pairs of processes (counting tinplating and galvanizing separately) showed the expected reduction in manhour requirement per unit product, equivalent to an increase in productivity. As shown in Table 26, observed increases in productivity (output per manhour) ranged from 26.5% to 271%, but four out of the five gains (averaged over both firms) fell in the narrower range 40-60%.

The mean absolute levels of productivity were still relatively low even in the new technology for demand-deposit accounting (60 items per manhour) and machining complex parts (0.45 parts per manhour). Detailed examination of the process charts and other data for these cases showed that there was still a great deal of manual operation in both although their central operations had been completely mechanized (i.e., account posting; metal-cutting). These two processes cannot be described as fully automatic, though they contain automatic operations. A considerable amount of further technological progress will be needed to reach a state even approximating full automation in these cases. While the four firms were all discussing possible further technological developments, there were no immediate plans for significant advances beyond the stage described here.

The other three new processes, all in steelmaking, were nearer to full automation as reflected in the relatively large absolute outputs per man-hour. There was no direct handling of materials in any of them and only a moderate amount of manually controlled indirect manipulation. Fairly modest additional mechanization of certain sequential operations, such as programmed loading and unloading of coils and automatic welding, would remove the last direct human effort. More sophisticated automatic control of running conditions, whether achieved by analog or digital means, would make relatively little difference to productivity, though it might improve quality or increase plant utilization.

Thus in all cases studied the installation of more highly mechanized equipment has been justified in terms of higher productivity, but without access to cost figures one cannot estimate whether the savings in manhours were paralleled by dollar savings.

It should be borne in mind that measurements covered direct production labor only. Added requirements for indirect labor involved in maintenance, planning and scheduling, parts-programming and so forth, may alter the

TABLE 21

Source of Variance	D.F.	V.R.	Significance Level
Between skill levels	2	114.21	P < 0.001
Between technologies	1	17.58	P < 0.001
Between individual parts	7	3.63	P < 0.05
SL x T	2	7.63	P < 0.01
SL x P	14	3.84	P < 0.01
T x P	7	0.57	

TABLE 22: ESTIMATED REQUIRED HIGH SCHOOL EDUCATION, MACHINING, FIRMS E & F

High School Education (years)	Average Manhours Per Part			Average Manhours as % of Total for each Technology Level		
	TL 1	TL 2	Change	TL 1	TL 2	Change
2.1-4.0	3.7	1.5	-2.2	98.7	66.8	-31.9
0.1-2.0	0.0	0.0	0.0	0.0	0.0	0.0
0	0.1	0.7	+0.6	1.3	33.2	+31.9

MEAN EDUCATIONAL LEVEL (years of high school)	TL 1	TL 2
	3.0	2.0

TABLE 23: ESTIMATED REQUIRED ON-THE-JOB EXPERIENCE, MACHINING FIRMS E & F

On-the-job Experience (months)	Average Manhours Per Part			Average Manhours as % of Total for each Technology Level		
	TL 1	TL 2	Change	TL 1	TL 2	Change
37-48	1.5	0.2	-1.3	39.5	9.1	-30.4
24-36	1.8	1.6	-0.2	47.4	72.7	+25.3
12-23	0.4	0.2	-0.2	10.5	9.1	-1.4
1-11	0.1	0.2	+0.1	2.6	9.1	+6.5

MEAN LENGTH OF EXPERIENCE (months)	TL 1	TL 2
	33.0	27.8

TABLE 24

Absolute reductions or increases in manhours per unit product associated with changes in technology: breakdown by lower, medium and higher skill levels.

Process	Technology	Product Unit	Total Manhours		Lower Skill Level		Medium Skill Level		Higher Skill Level	
			Manhours Per Unit	Reduction or Rise	Manhours Per Unit	Reduction or Rise	Manhours Per Unit	Reduction or Rise	Manhours Per Unit	Reduction or Rise
Demand deposit accounting (Bank 1)	Machine aided	1000 items	30.3		0.0		30.3		0.0	
	Computerized	1000 items	16.0	-14.3	0.7	+0.7	12.9	-17.4	2.4	+2.4
Demand deposit accounting (Bank 2)	Machine aided	1000 items	21.5		0.0		21.5		0.0	
	Computerized	1000 items	17.0	-4.5	0.7	+0.7	14.7	-6.8	1.6	+1.6
				-9.4		+0.7		-12.1		+2.0
Annealing	Batch	10 tons	2.1		0.1		1.6		0.4	
(Steelfirm 1)	Continuous	10 tons	1.3	-0.8	0.0	-0.1	0.9	-0.7	0.4	0.0
Annealing	Batch	10 tons	2.5		0.0		1.7		0.8	
(Steelfirm 2)	Continuous	10 tons	1.6	-0.9	0.0	0.0	1.0	-0.7	0.6	-0.2
				-0.9		-0.1		-0.7		-0.1
Galvanizing	Sheet	10 tons	12.8		1.5		9.6		1.7	
(Steelfirm 1)	Strip	10 tons	3.9	-8.9	0.1	-1.4	2.0	-7.6	1.8	+0.1
Tinning	Sheet	100 base box	10.9		0.2		7.6		3.1	
(Steelfirm 2)	Strip	100 base box	2.9	-8.0	0.1	-0.1	1.6	-6.0	1.2	-1.9
				-8.5		-0.8		-6.8		-0.9
Machining of Parts (Firm 1)	Conventional	1 part	3.8		0.3		1.1		2.4	
	N/C	(average of 2)	2.7	-1.1	0.2	-0.1	0.6	-0.5	1.9	-0.5
Machining of Parts (Firm 2)	Conventional	1 part	3.8		0.1		0.7		3.0	
	N/C	(average of 6)	2.0	-1.8	0.2	+0.1	0.2	-0.5	1.7	-1.3
				-1.4		0.0		-0.5		-0.9

TABLE 25

Redistribution of manhour inputs between lower, medium and higher skill levels associated with changes in technology.

Process	Technology	Total Manhours Per Unit	Lower Skill Levels		Medium Skill Levels		Higher Skill Levels	
			Manhours as % of Total	Difference %	Manhours as % of Total	Difference %	Manhours as % of Total	Difference %
Demand deposit accounting (Bank 1)	Machine aided	30.3	0.0		100		0.0	
	Computerized	16.0	4.4	+4.4	80.6	-19.4	15.0	+15.0
Demand deposit accounting (Bank 2)	Machine aided	21.5	0.0		100		0.0	
	Computerized	17.0	4.0	+4.0	86.4	-13.4	9.4	+9.4
				+4.2		-16.4		+12.2
Annealing	Batch	2.1	4.8		76.2		19.0	
(Steelfirm 1)	Continuous	1.3	0.0	-4.8	69.2	-7.0	30.8	+11.8
Annealing	Batch	2.5	0.0		68.0		32.0	
(Steelfirm 2)	Continuous	1.6	0.0	0.0	67.5	-5.5	37.5	+5.5
				-2.4		-6.2		+8.6
Galvanizing	Sheet	12.8	10.9		75.7		13.3	
(Steelfirm 1)	Strip	3.9	2.6	-8.3	51.3	-24.4	46.2	+32.9
Tinning	Sheet	10.9	1.8		69.7		28.4	
(Steelfirm 2)	Strip	2.9	3.4	+1.6	55.2	-14.5	41.3	+12.9
				-3.3		-19.4		+22.9
Machining of Parts (Firm 1)	Conventional	3.8	7.9		28.9		63.2	
	N/C	2.7	7.4	-0.5	22.2	-6.7	70.4	+7.2
Machining of Parts (Firm 2)	Conventional	3.8	2.6		18.4		79.0	
	N/C	2.0	9.5	+6.9	9.5	-8.9	81.0	+2.0
				+3.2		-7.8		+4.6

relative manpower demands of old and new processes. But the relative effect is judged likely to be small in all cases except perhaps the continuous steel-finishing processes. Further research will be required to ascertain whether this surmise is correct.

5.2 Distribution of Skill-levels

Initial skill-distribution

The manhour requirements of the older processes were in all cases concentrated in the lower-middle range of the six or seven skill-levels distinguished. In no case was there a preponderance of bottom-level skills, and none of the processes required a significant amount either of direct physical work such as manipulation or transportation of materials, or of simple repetitive mental work such as addition or copying of figures. This reflects the fact that all of the processes studied were already highly mechanized, using electric or mechanical power wherever a significant amount of energy was needed to effect changes in the materials. Nearly all elementary data-processing had already been mechanized too, the major exceptions being inspection of coated steel sheets and reading account-numbers and dollar-amounts from handwritten checks.

Thus the bulk of the labor force in the older processes did little direct manipulation either of materials or information but were engaged in controlling the action of relatively simple machinery such as conveyors and adding/listing machines; that is, in machine-operation and first-level indirect control. Overall (supervisory) control was exercised by a few men of higher skill, under an overall plan laid down by the management, and by planning and scheduling staffs whose contributions were not measured here.

Expressed in skill-distributions, then, the typical pattern was a skewed unimodal distribution with a short tail at the lower end and a long one at the upper end.

Changes in mean skill-level

All the processes showed statistically significant changes in mean skill-level with increasing automation and, except in numerical control, all the changes were in the upward direction. Thus the evidence tells preponderantly against Bright's hypothesis.

But the increases (and decreases) were small in absolute terms, and there was no sign of the major upgrading of the workforce predicted by earlier writers. At most, the increase amounted to the equivalent of a year or two of extra high-school education or a few months of job-experience. Only in one case (demand-deposit accounting) was there an absolute increase in per unit manpower requirement at the top skill-level, though there were relative increases in the other four cases. Taken together, then, the results show a small but definite tendency for the skill-levels of the workforce to increase in newer processes relative to the older ones.

Changes in skill-levels by type of process

The processes studied were of very different types, and it is somewhat surprising that their skill-profiles were so much alike.

Commercial data-processing (demand-deposit accounting) required an initially high mean level of education and showed little change with automation except that a small proportion of both lower and distinctly higher skill-levels were added for the newer process, increasing the spread around a slightly increased mean level.

Both steel processes, which were instances of continuous bulk processes for homogeneous raw-materials, showed initially broad irregular distributions whose spread (range) did not change much with the newer technology though the mean increased somewhat.

Data from the machining process represented a relatively smaller sample (only a few parts out of the great number produced) and the distributions were subject to sampling variation. Valid conclusions cannot be drawn concerning changes in the range of skill levels in this case, though the decline in average level is likely to be real. The process is a combination of many distinct operations with different skill-requirements variously assorted for each part. The numerical-control technology was also less well "run-in" than the other new processes, and its true skill demands were relatively difficult to estimate. It seems reasonable to conjecture, however, that the upper tails of the skill-distribution are curtailed in the newer process, producing a net reduction in range associated with a modest decline in mean level.

Skill-distributions in the newer technologies

The general conclusion may be drawn from the results that fully automated processes tend to require direct labor at several levels of skill uniformly spread over the work-force, with relatively small but similar numbers required at each of a series of levels from totally unskilled through highly skilled. This picture is disturbed wherever there are remaining major operations with a high manual content, such as dollar-amount encoding in demand deposit accounting, or hand-finishing in n/c machining. In other words, the preponderance of "semi-skilled" labor working specifically on one type of operation is characteristic of partly-automated processes and its elimination leaves a more balanced workforce.

5.3 Education and job-experience

The results of the analyses of estimated educational and on-the-job experience requirements were found to be in good agreement with the results based on job-evaluation, and cast additional light on some of the phenomena underlying the observed changes in skill level.

Check processing and account posting

Achieving a fairly advanced level of high school education appeared to be a prerequisite for the operators of the computerized system, as it was for operators in the older system. The relatively small amounts of experience considered necessary for reaching a satisfactory level of performance confirmed that the specific skill content of most tasks could

TABLE 26

Directly Measured Productivity Changes in Four Selected Processes

Process	Firm	Technology	Productivity (Output/Manhour)		Productivity Increase
Demand-deposit accounting	A	Old	33.0 items		89.4%
		New	62.5 "		
	B	Old	46.5 "		26.5%
		New	58.8 "	Mean	58.0%
Annealing steel strip	C	Old	4.76 tons		61.6%
		New	7.69 "		
	D	Old	4.00 "		56.3%
		New	6.25 "	Mean	59.0%
Coating steel strip	C	Old	0.78 "		233.3%
		New	2.6 "		
	D	Old	9.3 base boxes		271.0%
		New	34.5 " "	Mean	252.2%
Machining aircraft parts	E	Old	0.263 parts		40.7%
		New	0.370		
	F	Old	0.263		90.1%
		New	0.500	Mean	65.4%

readily be mastered given a sufficiently broad general educational basis: the skill level changes associated with the introduction of the computer system were evidently linked with an upward shift in the length of experience required. It would seem that more than half of all employees had sufficient high school education to adapt rapidly to the tasks needed at any point and at every operating level of the new system.

Steel finishing processes (annealing and coating)

For performing most tasks on the operating side, extended experience on the process itself was undoubtedly a more important consideration than the possession of formal educational qualifications in the case of most operators: more than half of the manhours on both the batch and the continuous processes required less than a high school education. For promotion within the operating team prolonged on-the-job experience appeared to be sufficient. However the results also indicated that overall control and supervision of the complete process was likely to fall to that minority of experienced operators who had either graduated or nearly graduated from high school and had subsequently gone through a fairly prolonged apprenticeship in the steel industry. The observed increases in skill-level characteristic of the newer systems thus seemed to derive partly from higher educational standards, but mainly from more extended experience on the process being operated or ones like it.

Machining of complex parts

The drop in mean skill-level associated with the introduction of numerically controlled machine tools was paralleled by marked reductions both in educational and in experience requirements. Whereas all conventional machinists needed more than 3 years of high school together with extended job-experience, a large proportion of n/c machine tool operators needed less than two years of high school and substantially less experience. Observations of the changes in job content indicated that nearly all of the detailed judgement and decision required for job performance had been transferred to the tapes actuating the n/c tools, and in the light of this the decreased requirements in education and experience were not surprising.

General educational impact of advanced technologies

Taken as a whole, and unless the processes studied are completely atypical, the results suggest the tentative generalization that educational requirements for direct labor involved in operating duties change very little with advancing technology. There was no suggestion anywhere that even the most highly skilled operators, and those carrying the heaviest responsibilities for the continued satisfactory operation of equipment, required education beyond high-school level. In this connection it is also worth noting that, with very few exceptions, managers at all levels with whom discussions were held attached little importance to formal education but rather insisted on the importance of direct experience either on the processes forming part of their own technology or in related processes.

§§ CHAPTER
6. MANPOWER PROJECTIONS AND POLICY IMPLICATIONS FOR SPECIFIC INDUSTRIES[*]

As indicated in Chapter 2, skill-profiles of the type given in Chapter 4 may be used to derive projections of future manpower and skill requirements in the relevant sections of the industries studied, by combining them with the following data:

1) Projected demand for the product-mix of the old and new processes for the period of projection.

2) Extent of "penetration" or "diffusion" of the new processes, i.e., the proportion of all producers using the old and new process.

While the research team does not claim expertise in these areas, an attempt has been made to provide plausible estimates, and the projections outlined below are given to illustrate the specific use that may be made of skill-profile data. Considerably fuller investigation would be needed to yield definitive results valid for manpower planning and other purposes. However, each of the specific projections made below has been scrutinized by managerial personnel familiar with the problems and prospects of the industry in question, who do not dispute our data or assumptions. If no unforeseen changes disturb the growth of demand and diffusion of new technology the forecasts made are likely to be reasonably accurate.

6.1 Demand-deposit accounting

The level of demand for check-processing in the U.S.A. as a whole has been reported for the years 1947-62 by the Bureau of Labor Statistics[**] and Table 27 gives a series of figures for projected demand for check-processing at five-year intervals to 1975 based on a linear extrapolation from the data for the years 1955 to 1960[***]. The total full-time-equivalent number of employees (direct labor) required to process these projected volumes using the old and the new technology were calculated, assuming 1,920 manhours per employee-year (40 hours per week, 48 weeks per year), and using the data summarized in Table 24 (averaged over the two firms studied) for the direct manhours required per unit product. The resulting projections for the total labor-force and for the Low, Medium and High skill-groups taken separately are given in Table 27 and graphed in Figures 21b and 22a,b.

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[*] This section is presented in outline only, pending further analysis and collation with statistical data drawn from independent sources.

[**] "Technological Trends in 36 Major American Industries", U.S. Department of Labor, Bureau of Labor Statistics Report, 1964, page 99; data provided by Federal Reserve Board.

[***] At 750 million checks/5 years; a logarithmic extrapolation at 28% growth per 5 years was also tested and found to yield only slightly different projections.

TABLE 27

CALCULATED MANPOWER REQUIREMENTS
DEMAND-DEPOSIT ACCOUNTING

YEAR	DEMAND* (in items x 10^9)	NUMBERS OF MEN REQUIRED							
		OLD TECHNOLOGY				NEW TECHNOLOGY			
		Low (0.0)+	Med (25.9)+	High (0.0)+	Total (25.9)+	Low (0.7)+	Med (13.8)+	High (2.0)+	Total (16.5)+
1950	1.9	---	25,600	---	25,600	700	13,700	2,000	16,400
1955	2.7	---	35,700	---	35,700	1,000	19,000	2,800	22,800
1960	3.4	---	45,900	---	45,900	1,200	24,400	3,500	29,100
1965	Extrapolated 4.2	---	56,000	---	56,000	1,500	29,800	4,300	35,600
1970	4.9	---	66,100	---	66,100	1,800	35,200	5,100	42,100
1975	5.7	---	76,200	---	76,200	2,100	40,600	5,900	48,600

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*Derived from data published by the Bureau of Labor Statistics, U.S.D.L., (in "Technological Trends in 36 major American Industries", ibid. page 103).

+Figures in brackets are manhours/1000 items by skill level averaged over firms A & B (Table 24).

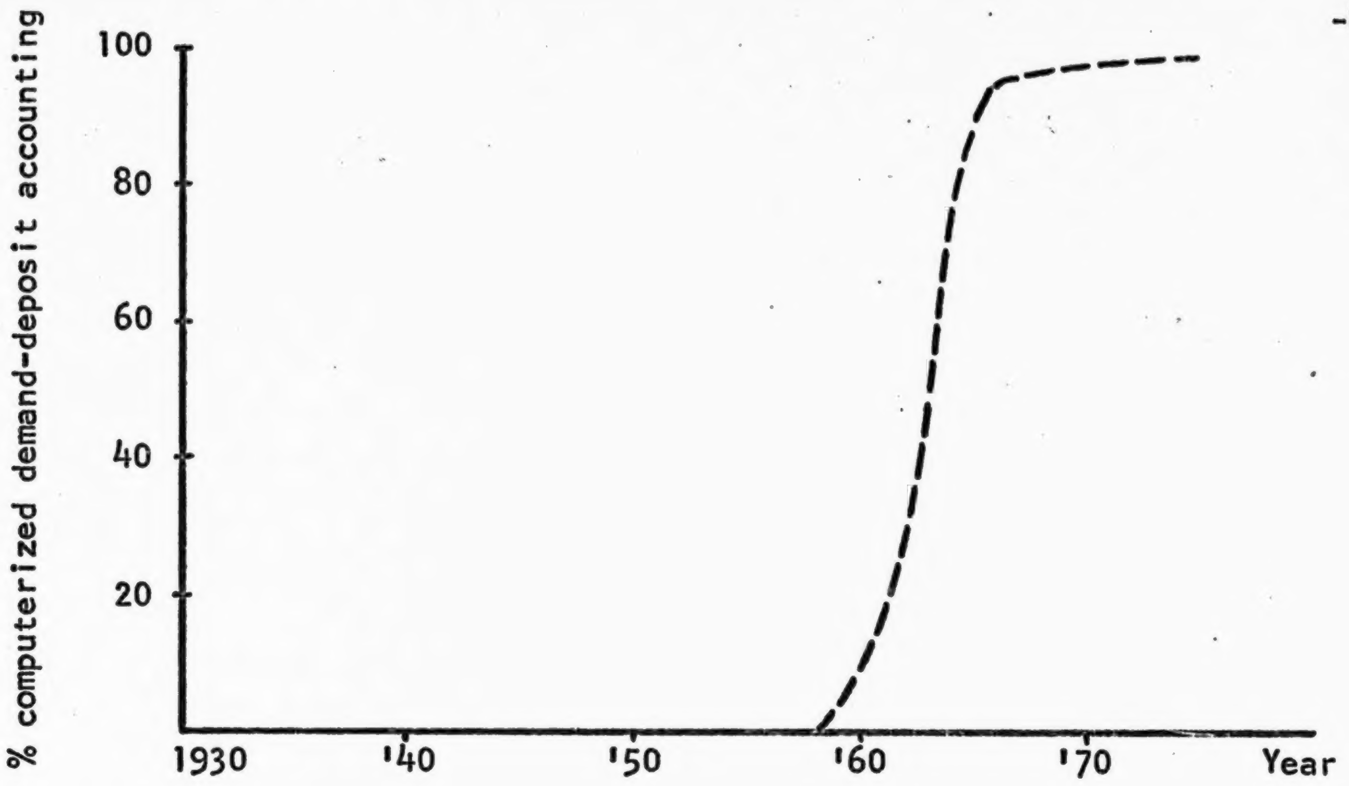

Fig. 21a: Estimated replacement of machine-aided hand processing by computerized processing in demand deposit accounting in Banks.

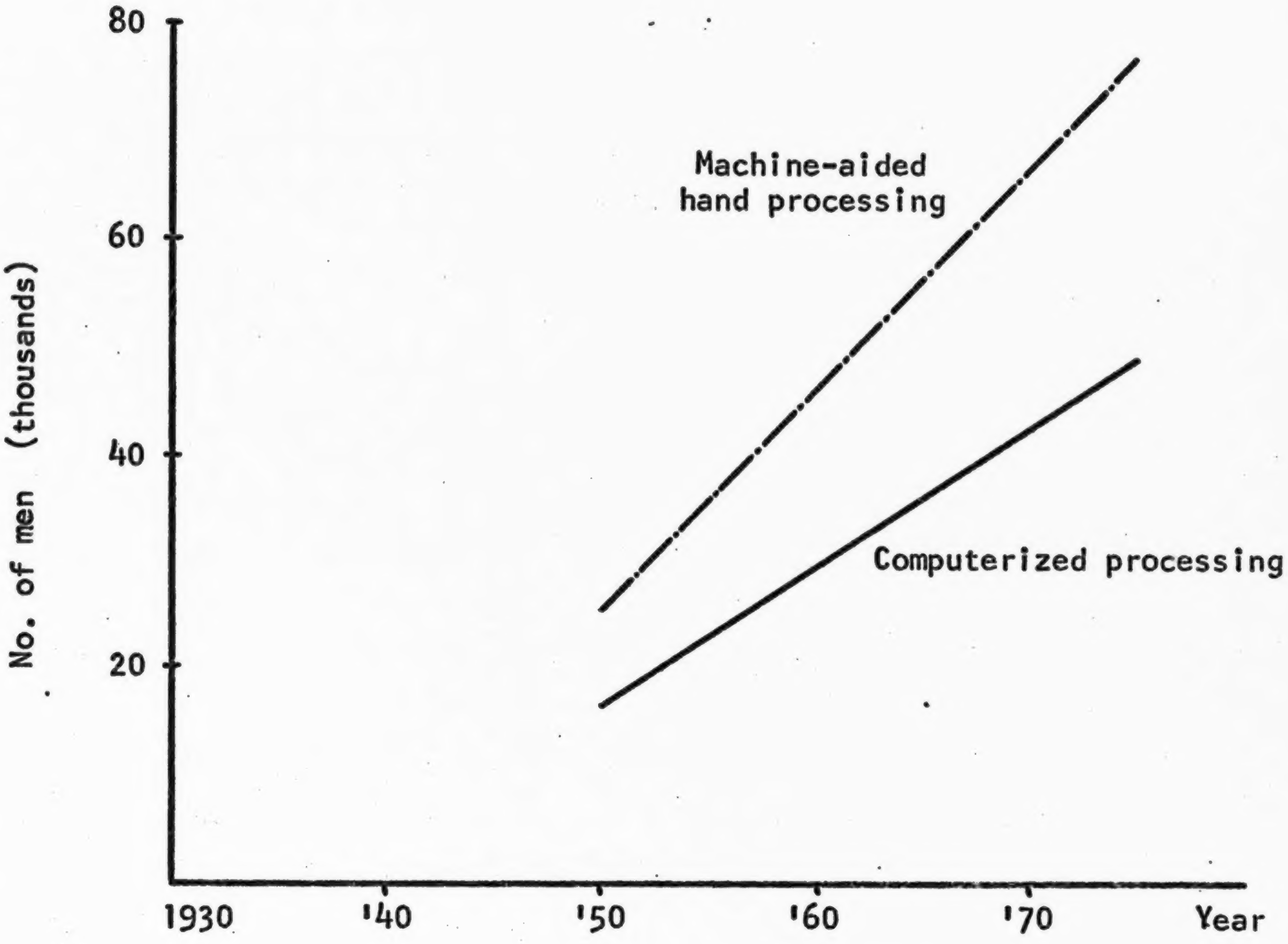

Fig. 21b: Total manpower projections based on assumption of 100% processing by older or newer technologies. Plotted from calculated values in Table 27.

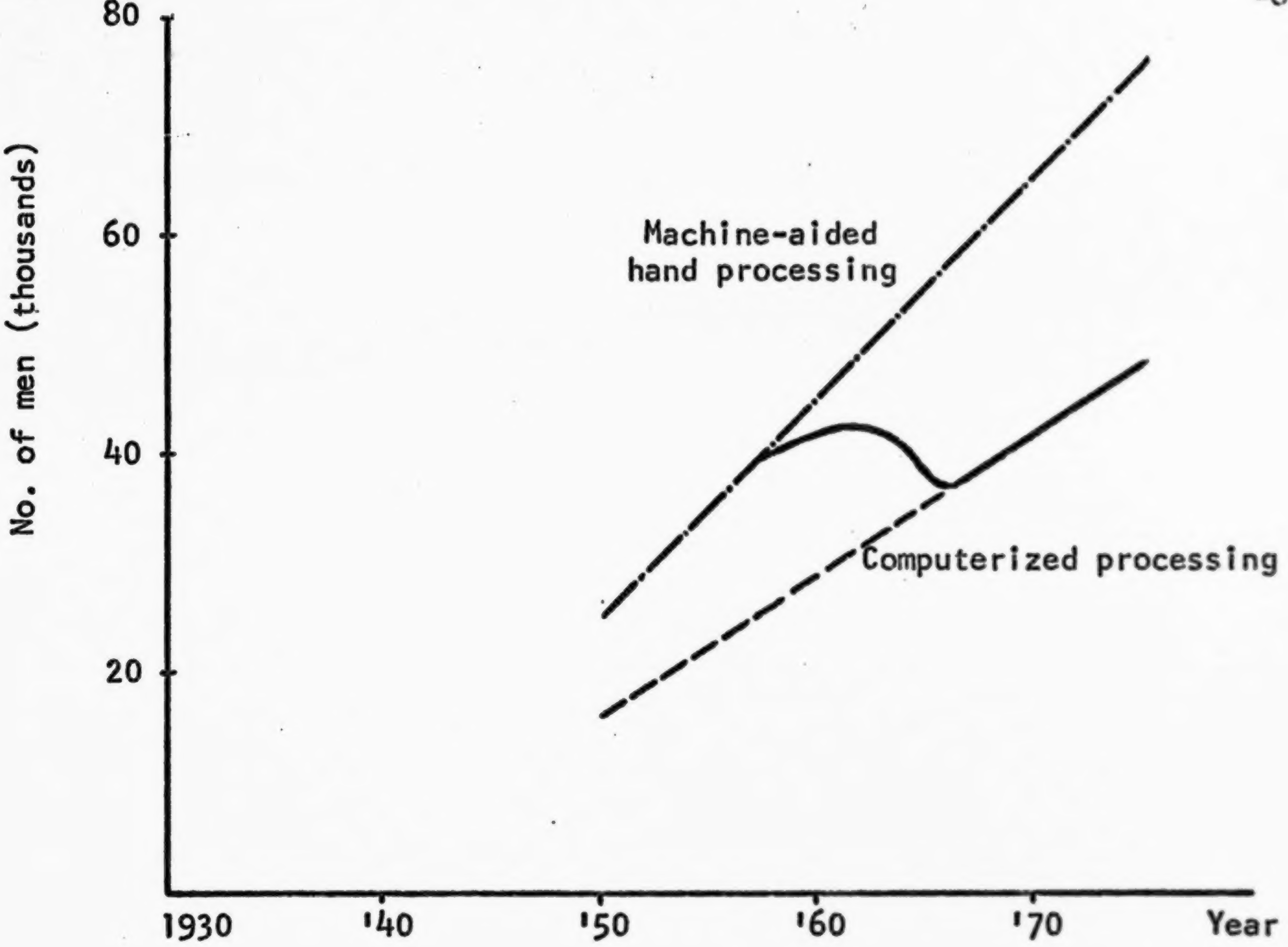

Fig. 22a: Estimated change in total manpower requirements due to introduction of electronic data processing in Banks.

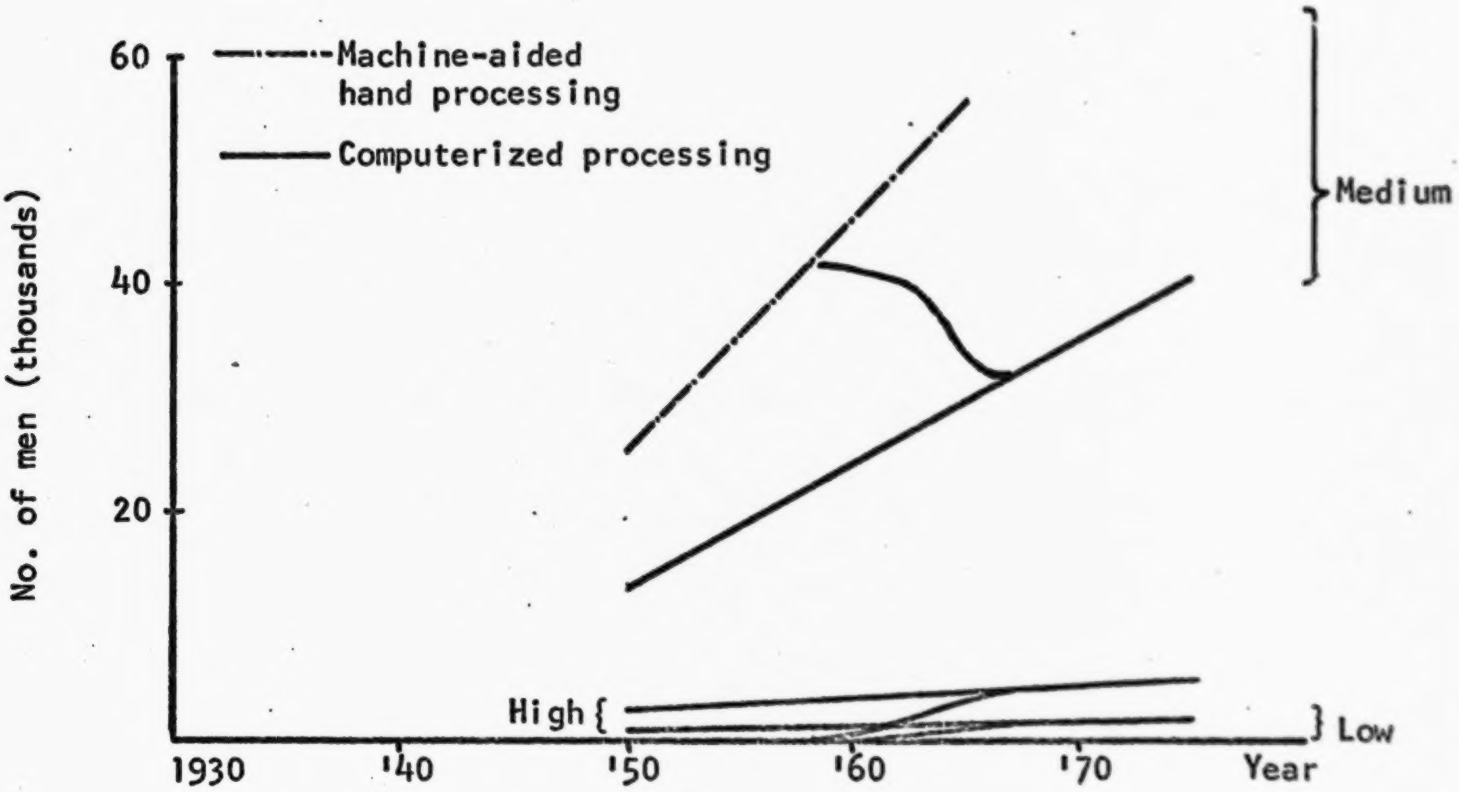

Fig. 22b: Estimated changes in requirements for manpower at different skill levels in demand-deposit accounting.

The curves represent projected manpower requirements based on the assumption that the older and the newer technologies respectively were responsible for 100% of the product (i.e., meeting all of the projected demand in the years in question).

No directly reported data were available on the "diffusion" of E.D.P. systems in demand-deposit accounting; collateral evidence* indicates that in 1959 there were no E.D.P. systems in use, while informants in the banking industry indicated that by 1965 perhaps 90% of check-processing in the U.S.A. had been transferred to EDP systems. A plausible view of the time-course of diffusion of EDP systems is thus given by the curve in Figure 21a, showing a relatively rapid and complete transition from the older to the newer system.

Applying these estimates of the probable rate of diffusion of EDP systems to the manpower projections calculated as above and expressed in Figure 21b, it seems that the actual total manpower requirement might be expected to follow a curve such as that shown in Figure 22a, the section between 1960 and 1965 being uncertain due to lack of exact data on the spread of E.D.P. technology. It will be noted that the curve shows what might be described as a plateau or a transient decline in manpower needs between the years 1963-1970; this is due to the fact that in this period growing demand was more than offset by the increased productivity of the new technology. After 1972 the total labor requirement may be expected to resume its upward trend,though at a lesser rate than that obtaining before 1963.

Assuming that the data of Table 24 accurately reflect the redistribution of skill-requirements due to the new technology, the division between skill-levels within these total projections evidently plays a very subsidiary part. The older process needed only "medium" skills, whereas the newer one needs some 10% of "high" skills, causing a sharp increase in demand for better-skilled workers in the years 1960-65, levelling off into a continued small annual increase (amounting to some 150 men per year) in labor-requirement at these higher levels after 1965 (see Figure 22b). However, as discussed in Chapter 5, these higher skills still fall well within the range of education and experience normally required in demand deposit accounting i.e., high-school graduation (no college education) and a few months of on-the-job experience.

Policy indications relative to demand-deposit accounting

Thus there seems to be no reason to adopt active manpower policies in relation to the demand-deposit sector of banking. There are no indications that major redundancies are likely to arise at lower skill levels, or that skill-shortages are even remotely likely to hinder continued growth. On the other hand the increase in overall employment due to increased demand for banking services will be of modest proportions.

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*see "Management Decisions to Automate", (Appendix B), O.M.A.T. Manpower/Automation Research Monograph No. 3 (undated).

. Further technological advances of a relatively minor kind, such as automatic MICR encoding of dollar amounts on checks or programmed reconciliation, would cause sufficient further productivity increases to offset even this modest rise. For instance, a further reduction of some 10% in per-unit labor requirements of the E.D.P. systems would cause the present "plateau" to be extended at least through 1975.

Thus the demand-deposit sector of banking appears to be entering the "labor-static" phase characteristic of highly automatic industries. (see Chapter 7 for further discussion of this point).

The reader is warned that these and all subsequent manpower projections must be treated with considerable caution because of uncertainties attaching both to projections of demand and of technological diffusion-rates. Numbers employed will also vary with changes in hours worked per year. A decline from the figure of 1,920 assumed here would require upward revision of projected employment.

6.2 Annealing of steel strip

Production data published in the 1965 edition of the Annual Statistical Report published by the American Iron and Steel Institute* were used to determine the level of demand for annealed steel products. These refer to cold rolled sheet and strip, both of which are annealed before further processing; the data cover a number of years in the period 1930-1964. A regression line was fitted to the data for 1950 through 1964, and extrapolated linearly to provide estimates of demand into the 'seventies, with results shown in Table 28.

The full-time-equivalent direct labor requirements for processing the projected volumes were derived from the per-unit manhours required for box and continuous annealing (averaged over the two firms studied) as shown in Table 24, 1,920 manhours again being assumed per employee year. The results of the calculations are given in Table 28 and Figures 23b and 24a,b; the upper and lower manpower-requirement curves represent the older and newer technologies and are constructed as if each technology were responsible for meeting 100% of the total demand.

Fairly reliable data were also available regarding diffusion of the newer technology of continuous annealing. The first continuous annealing lines came into operation in the late 'forties and by 1965 the replacement of the older box-annealing process was virtually complete in the sense that most steelworks had installed continuous lines alongside their box annealing capacity (see Figure 23a). It is estimated that at present about 2/3 of all annealed product is being processed continuously. The remaining one-third is still produced by the older method and steel-industry experts express the opinion that, though box annealing may undergo further technological development, the latter process will continue to be used alongside continuous annealing.

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*Drawn from the Statistical Abstract of the United States, U.S. Department of Commerce, 1965.

TABLE 28

CALCULATED MANPOWER REQUIREMENTS
STEEL STRIP ANNEALING

YEAR	DEMAND (in short tons x 10^6)		NUMBERS OF MEN REQUIRED							
			OLD TECHNOLOGY				NEW TECHNOLOGY			
	Actual	Calculated*	Low (0.05)+	Med (1.65)+	High (0.6)+	Total (2.3)+	Low (0.0)+	Med (0.95)+	High (0.5)+	Total (1.45)+
1940	4.6		10	400	140	550	-	230	120	350
1950	12.6		30	1,100	400	1,530	-	620	330	950
1955	19.4		50	1,700	610	2,360	-	960	510	1,470
1960	18.2		50	1,600	570	2,220	-	900	470	1,370
1963	18.9		50	1,600	590	2,240	-	940	500	1,440
1964	22.0		60	1,900	690	2,650	-	1,090	570	1,660
1965		21.5	60	1,800	670	2,530	-	1,060	560	1,620
1970		23.9	60	2,100	750	2,910	-	1,180	620	1,800
1975		26.4	70	2,300	830	3,200	-	1,300	690	1,990

* Derived by extrapolation from regression line fitted to demand data for 1950 through 1964.

+ Figures in brackets are manhours/10 tons by skill level averaged over firms C & D (Table 24).

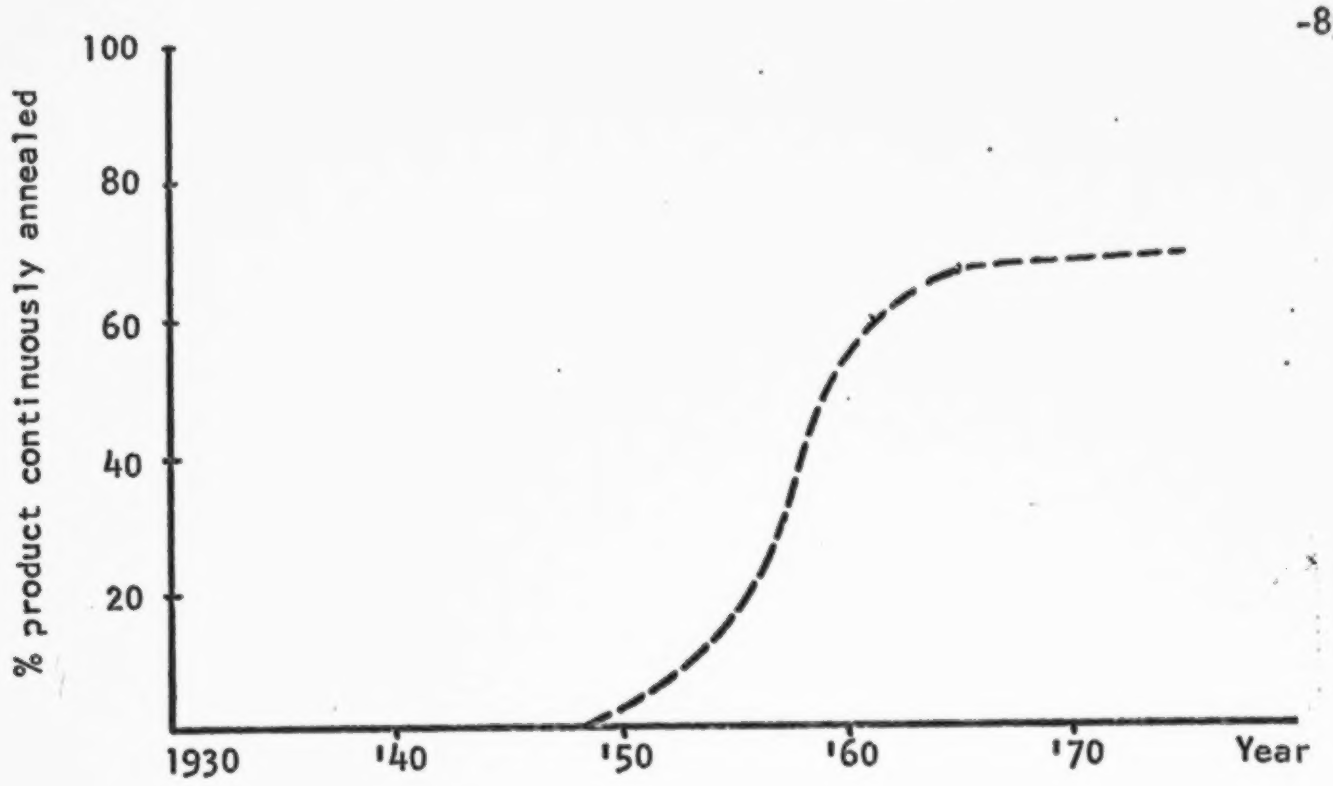

Fig. 23a: Estimated replacement of box (batch) annealing by continuous strip annealing.

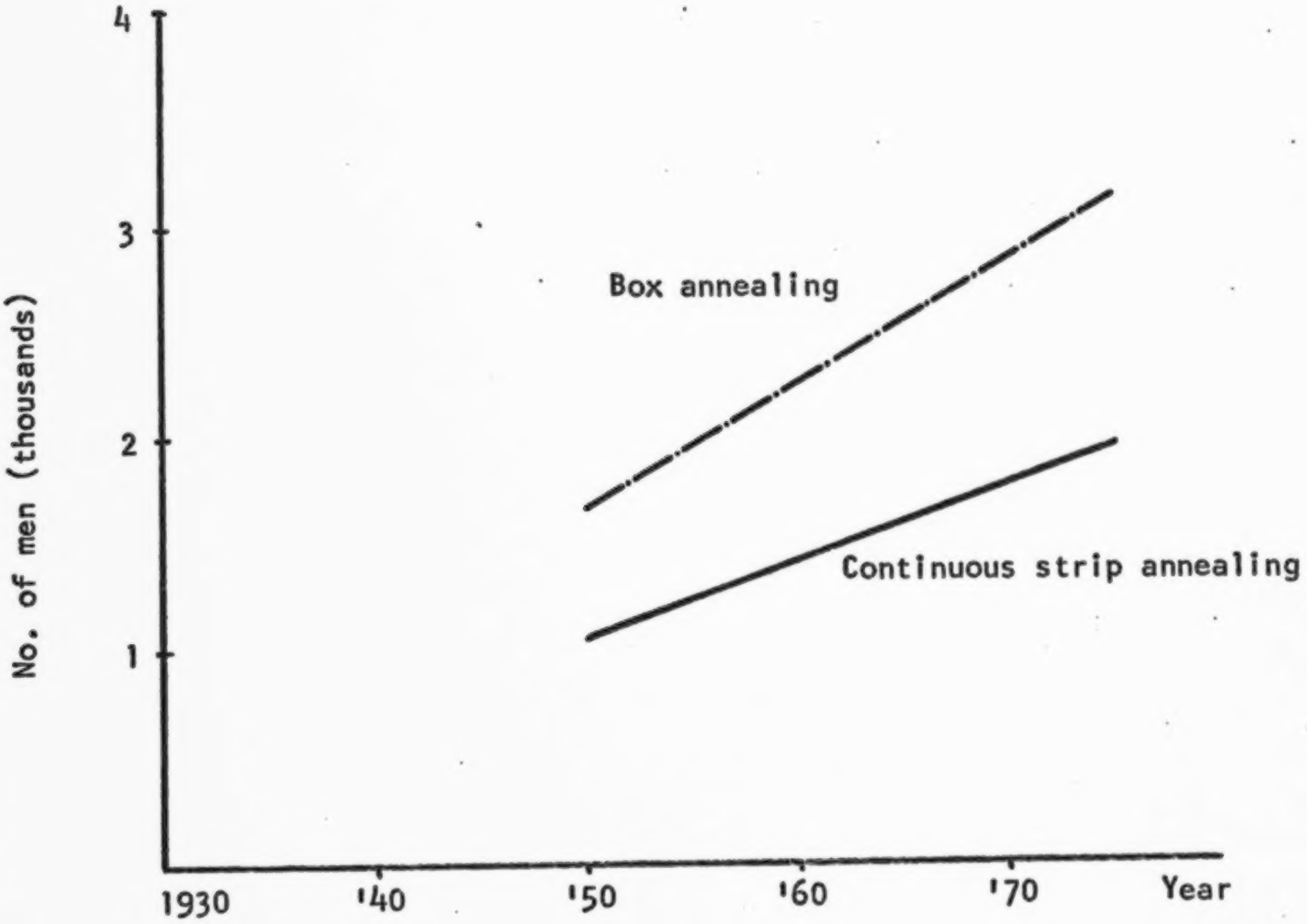

Fig. 23b: Total manpower projections based on assumption of 100% production by older or newer processes. Plotted from calculated values in Table 28.

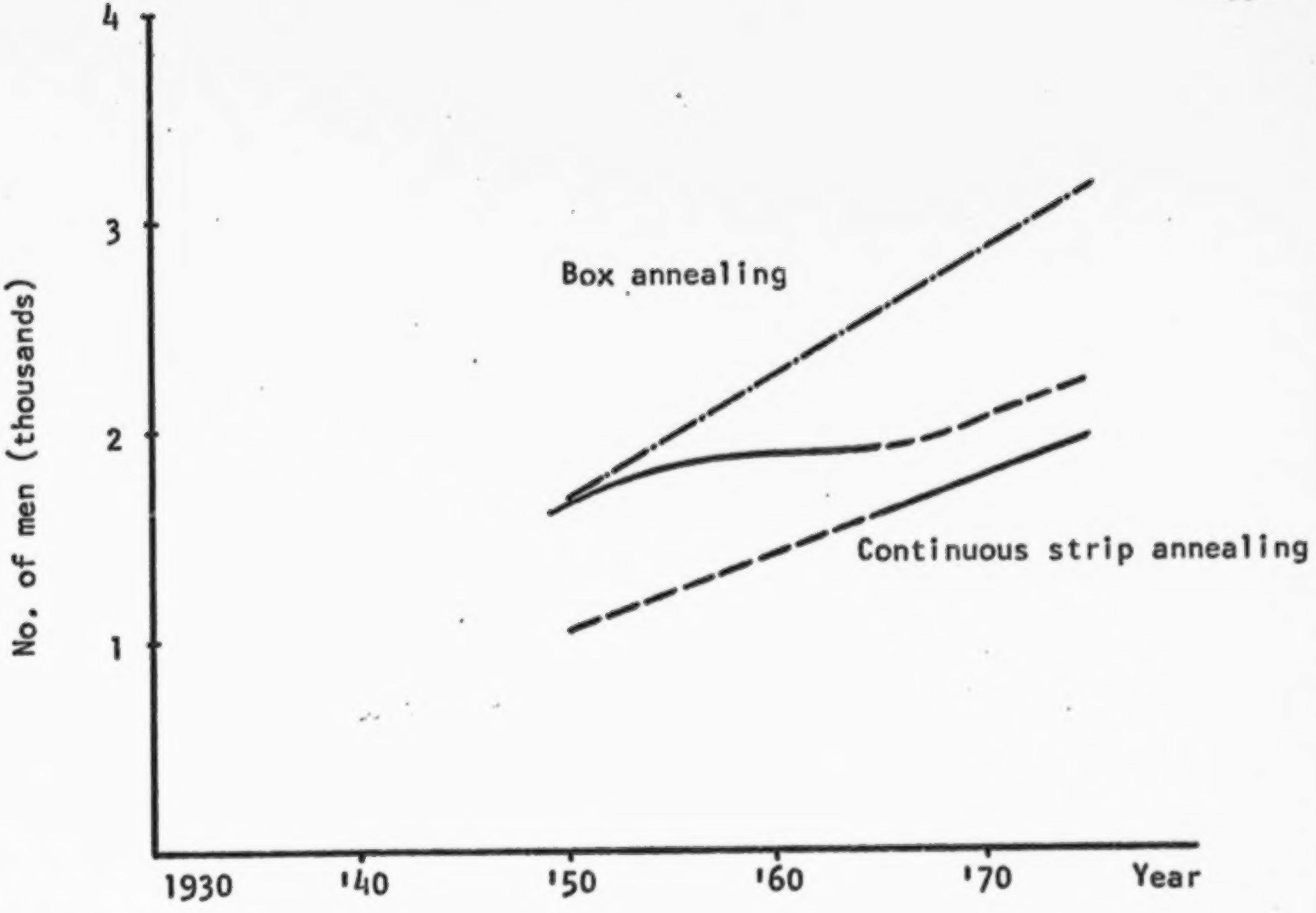

Fig. 24a: Estimated change in total manpower requirements due to introduction of new technology for annealing steel strip. Continuous annealing will not completely displace box annealing.

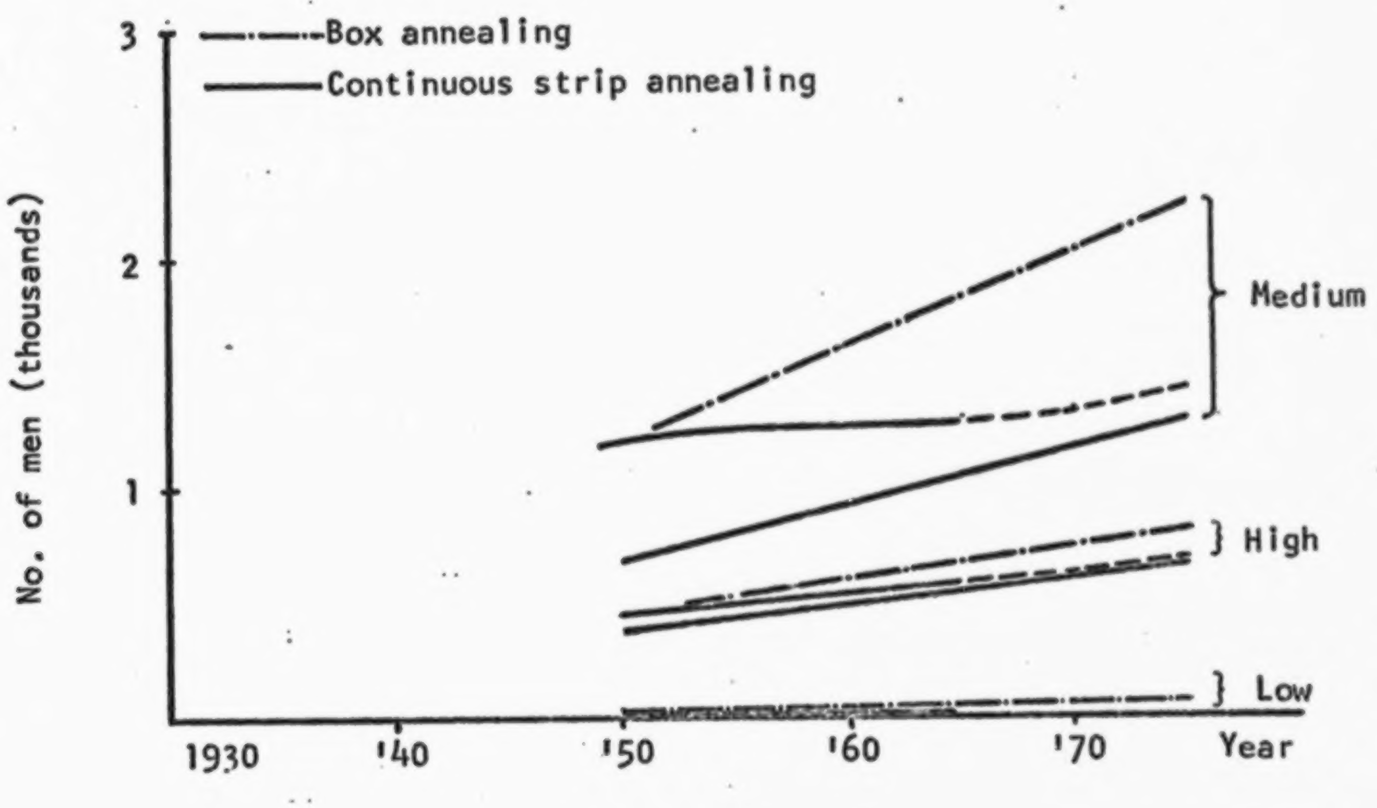

Fig. 24b: Estimated changes in requirements for manpower at different skill levels in annealing steel strip.

These considerations have been allowed for in Figure 24a. The curve showing the anticipated total manpower requirement only approaches the line representing the manpower requirements of the newer technology but does not join it, since about one third of the product continues to be made by the older method. The curve shows a distinct plateau between 1955 and 1965, and the total labor requirements, after a brief leveling off, may therefore be expected to continue rising from now onwards (assuming that the demand is correctly projected) at a somewhat lower rate than in the late 'forties and the early 'fifties.

As shown in Figure 24b the principal effect of the changeover is on medium skill-levels and there is very little impact on higher levels. Lower levels comprise a negligible proportion of the manpower requirements both before and after the change.

6.3 Coating processes for steel strip

Production figures reflecting the level of demand for galvanized sheet and strip, and for tin and terne plate*, were again extracted from the 1965 edition of the American Iron and Steel Institute's Statistical Report (reproduced in Statistical Abstract of the United States, ibid.). To obtain projections, only the post-1950 data were used in constructing regression lines. The data for 1930 and 1940 were omitted from the calculations since there was discontinuity probably associated with the Second World War.

The numbers of full-time-equivalent operators needed to produce the projected volumes of galvanized and tinned product respectively were calculated on the basis of the per unit manhours by skill-level derived from direct observation and shown in Table 24 using the previous assumption of 1,920 manhours per employee-year.

Galvanizing sheet and strip: The calculated values for future demand for galvanized product are shown in Table 29. Multiplying these projected demands by the total per-unit manhours for the older and newer process, the upper and lower lines in Figures 25b and 26a are obtained. The corresponding calculations are given in Table 29, which also contains breakdowns of the totals by low, medium and high skill level (see also Figure 26b). The upper and lower lines in Figures 25b and 26a indicate the total manpower that would be required if either the older or the newer technologies were used exclusively to meet the total projected demand.

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*In the source material, the production figures for tinplating are given jointly with those for terne plating, which is a process of coating steel strip with a layer of tin and lead. Since this latter process has undergone a technological change closely parallel to tinplating, and the volume of terne plate produced constitutes at most 10% of the combined tin and terne plate volume, it was considered justifiable to base the projection calculations on the total production figures.

The diffusion of continuous-galvanizing technology can be estimated with some confidence from the technical literature. Hot-dip sheet galvanizing was the dominant process until the late '40's when many steelworks started to install continuous lines. Thereafter the displacement of the older process was extremely rapid,and by 1965 only three works in the whole of the U.S. made any of their product by hot dipping. The curve illustrating the probable diffusion rate is shown in Figure 25a, the rapidity of the changeover being accounted for by the enormously greater productivity of the newer process as compared with the older (cf. Table 26).

Figure 26a shows the estimated total manpower requirement taking diffusion into account. There appears to have been a pronounced decline through 1960, and not until the late '70's will the number of operators on continuous galvanizing again equal the number employed on the older process at its peak in the early '50's.

Here again the main impact is on medium skill-levels (Figure 26b), which decline to under half their peak requirement. Lower levels also show a marked drop, while higher levels maintain their previous small rate of increase.

Tin plating: The manpower projections for galvanizing recur in exaggerated form in the case of tinplating. Use of the total per-unit manhours from Table 24 to obtain manpower projections involved a certain amount of complication, since Base Boxes to which the manhours were related, are a measure of area-of-surface-coated and the production figures were given in tons. With help from steelworks personnel a conversion was effected permitting manpower projections to be derived from the data for estimated demand in tons*.

The upper line in Figures 27b and 28a represents the total manpower needed if the demand throughout the period considered were to be completely met by means of the hot-dip tinning process; similarly the lower line indicates the manpower needed on the assumption of 100% production by continuous tin plating (see also Table 30).

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*The approximate thickness of the steel sheets to which tin coating is applied is expressed in pounds per base box and is referred to as the "basis weight". Average basis weights of the product mixes on the Hot Dip line and on the Electrolytic line were obtained from Firm C, a large producer of tin plated product. The basis weights indicated were 90 lb. per base box and 85 lb. per base box respectively, and were considered to be representative of tin plating in general. These basis weights were used to convert the manhour per 100 base box figures on the skill distributions to manhour per ton units for use in conjunction with the production tonnage given by the source.

TABLE 29

CALCULATED MANPOWER REQUIREMENTS
SHEET AND STRIP GALVANIZING

YEAR	DEMAND (in short tons x 10^6)		NUMBERS OF MEN REQUIRED							
			OLD TECHNOLOGY				NEW TECHNOLOGY			
	Actual	Calculated[*]	Low (1.5)[+]	Med (9.6)[+]	High (1.7)[+]	Total (12.8)[+]	Low (0.1)[+]	Med (2.0)[+]	High (1.8)[+]	Total (3.9)[+]
1930	1.2		95	600	105	800	6	125	115	146
1940	1.7		135	850	150	1,135	9	180	160	349
1950	2.3		180	1,150	210	1,540	12	240	215	467
1955	2.9		230	1,450	260	1,940	15	300	270	585
1960	3.1		240	1,550	280	2,070	16	320	290	626
1963	4.1		320	2,050	360	2,730	21	430	380	831
1964	4.5		350	2,250	400	3,000	23	470	420	913
1965		4.4	340	2,200	390	2,930	23	460	410	893
1970		5.1	400	2,560	460	3,420	27	530	480	1,037
1975		5.9	460	2,940	520	3,920	31	610	550	1,191

[*] Derived by extrapolation from regression line fitted to demand data for 1950 through 1964.

[+] Figures in brackets are manhours/10 tons by skill level reproduced from Table 24.

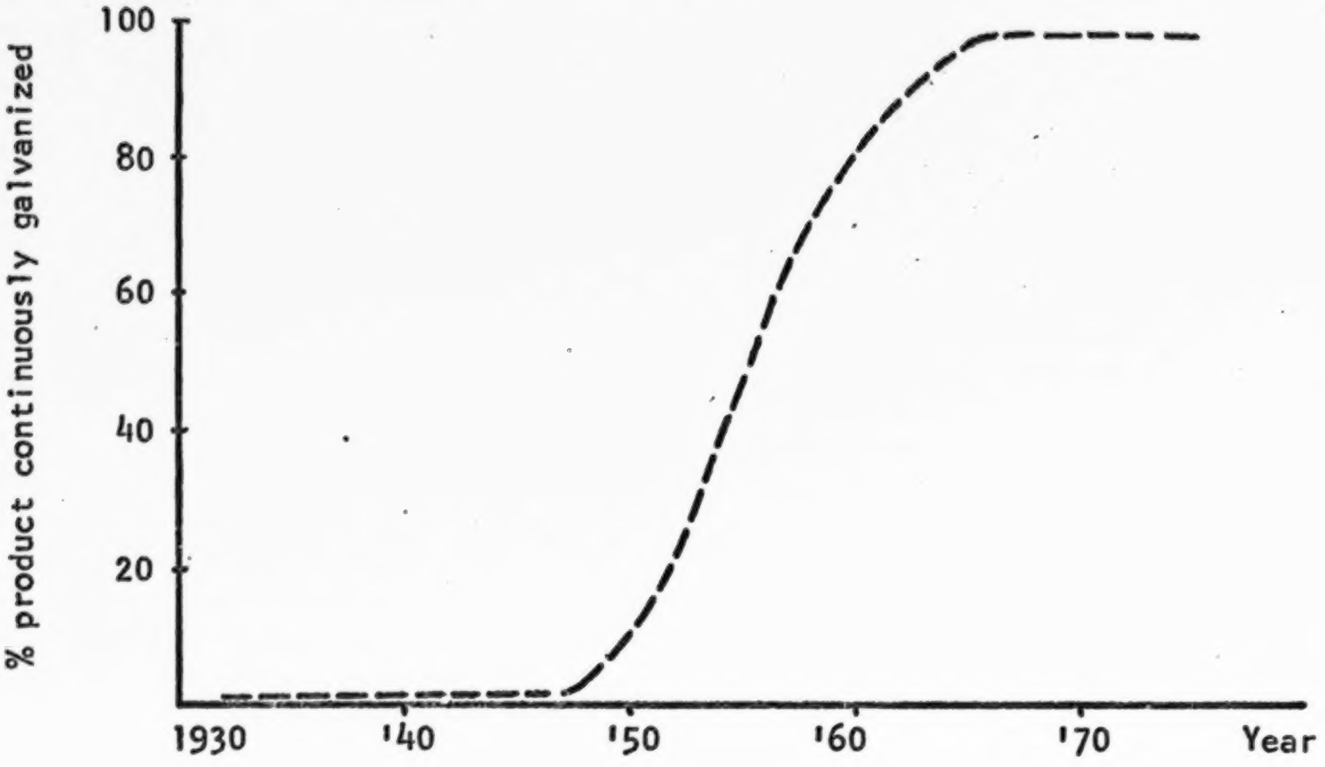

Fig. 25a: Estimated replacement of sheet galvanizing by continuous strip galvanizing.

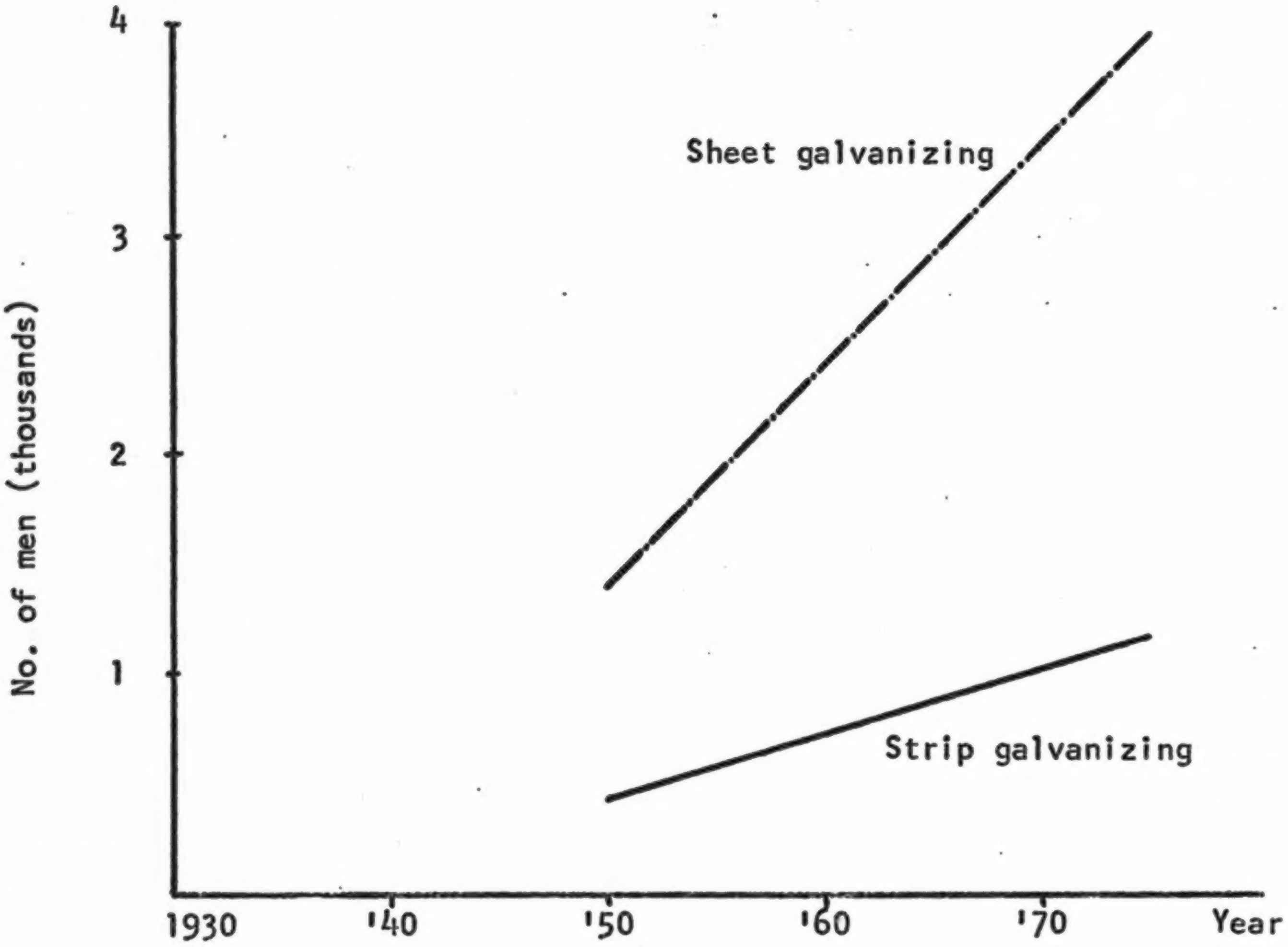

Fig. 25b: Total manpower projections based on assumption of 100% production by older and newer processes. Plotted from calculated values in Table 29.

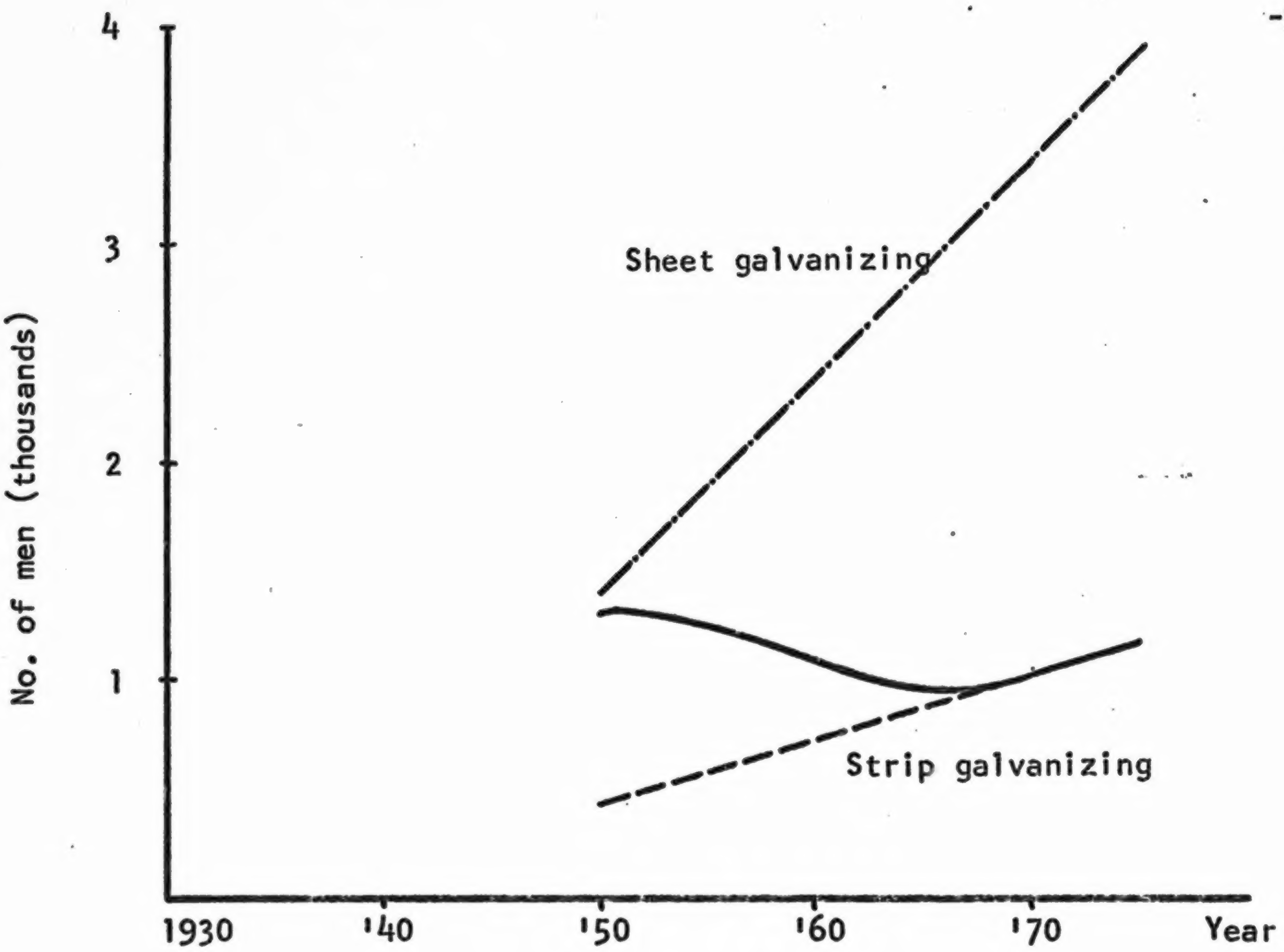

Fig. 26a: Estimated change in total manpower requirements due to introduction of new technology for galvanizing.

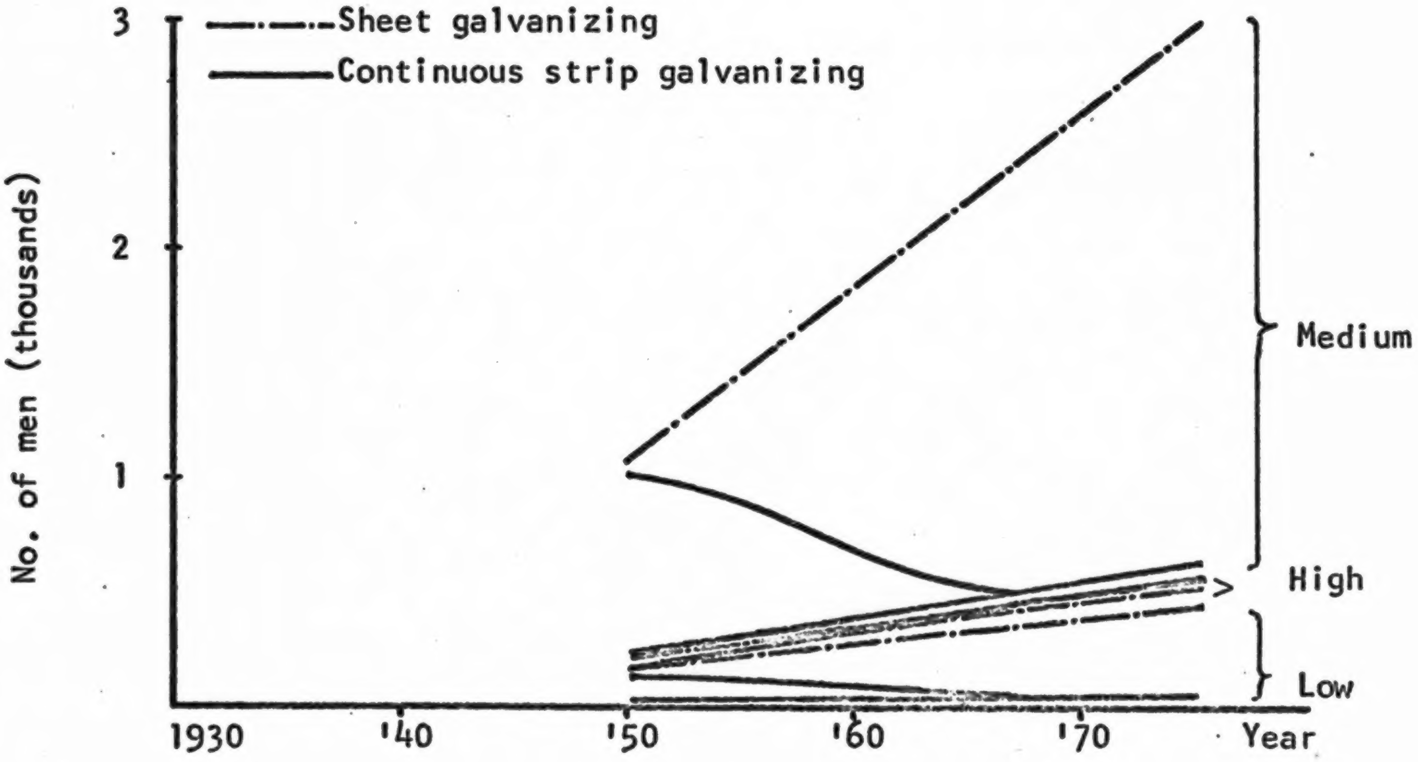

Fig. 26b: Estimated changes in requirements for manpower at different skill levels in galvanizing.

TABLE 30

CALCULATED MANPOWER REQUIREMENTS

TIN AND TERNE PLATING

YEAR	DEMAND (in short tons x 10^6)		NUMBERS OF MEN REQUIRED							
			OLD TECHNOLOGY				NEW TECHNOLOGY			
	Actual	Calculated*	Low (0.2)+	Med (7.6)+	High (3.1)+	Total (10.9)+	Low (0.1)+	Med (1.6)+	High (1.2)+	Total (2.9)+
1930	1.9		40	1,670	680	2,390	20	370	280	670
1940	2.7		60	2,380	970	3,410	30	530	400	960
1950	4.6		110	4,050	1,700	5,860	60	900	680	1,640
1955	5.2		120	4,570	1,870	6,560	60	1,020	770	1,850
1960	5.9		140	5,190	2,120	7,450	70	1,160	870	2,100
1963	4.9		110	4,310	1,760	6,180	60	960	720	1,740
1964	5.4		130	4,750	1,940	6,820	70	1,060	800	1,930
1965		5.4	130	4,820	1,940	6,890	70	1,080	800	1,950
1970		5.6	130	4,990	2,060	7,180	70	1,120	820	2,010
1975		5.8	130	5,170	2,080	7,380	70	1,160	850	2,080

* Derived by extrapolation from regression line fitted to demand data for 1950 through 1964.

+ Figures in brackets are manhours/100 Base Boxes by skill level reproduced from Table 24; 100 Base Boxes were taken to correspond to a basis weight of 9000 lbs. on the older technology and of 8500 lbs. on the newer technology (see footnote pg. 109).

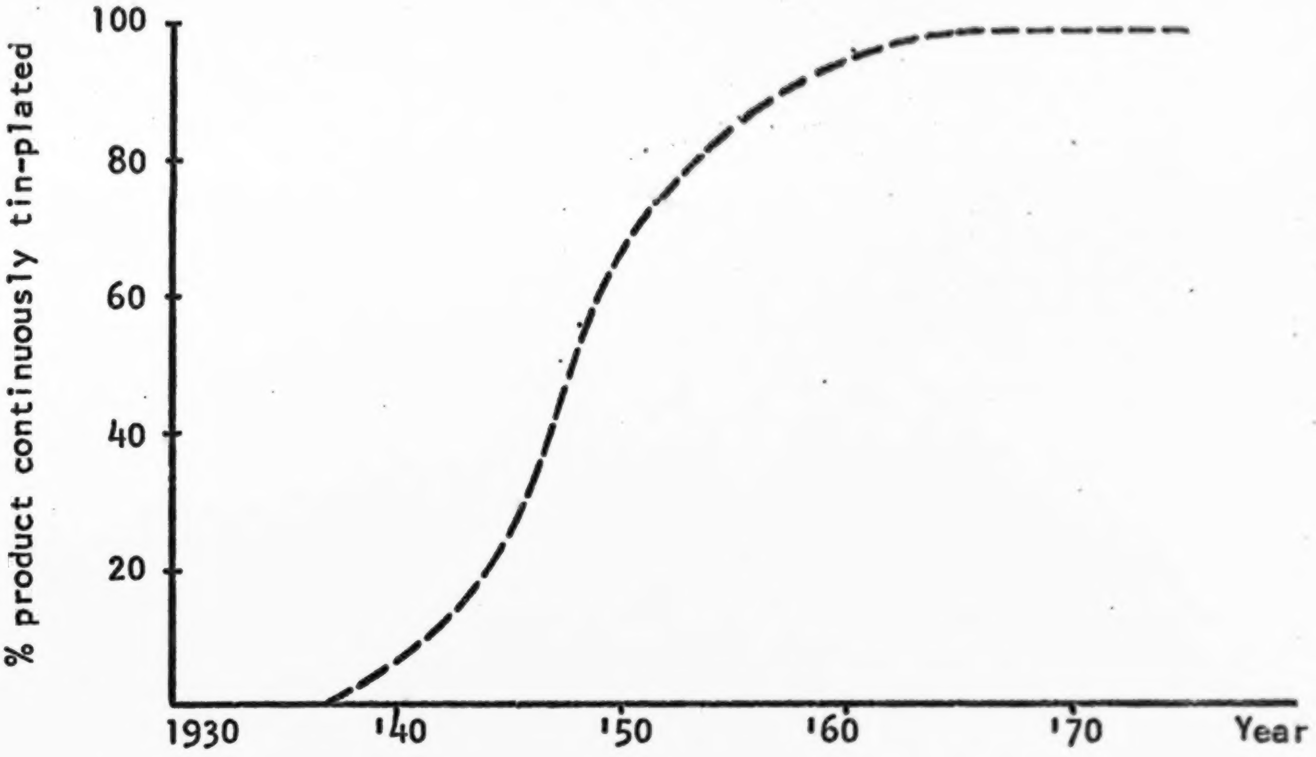

Fig. 27a: Estimated replacement of hot-dip tinning by continuous electrolytic plating.

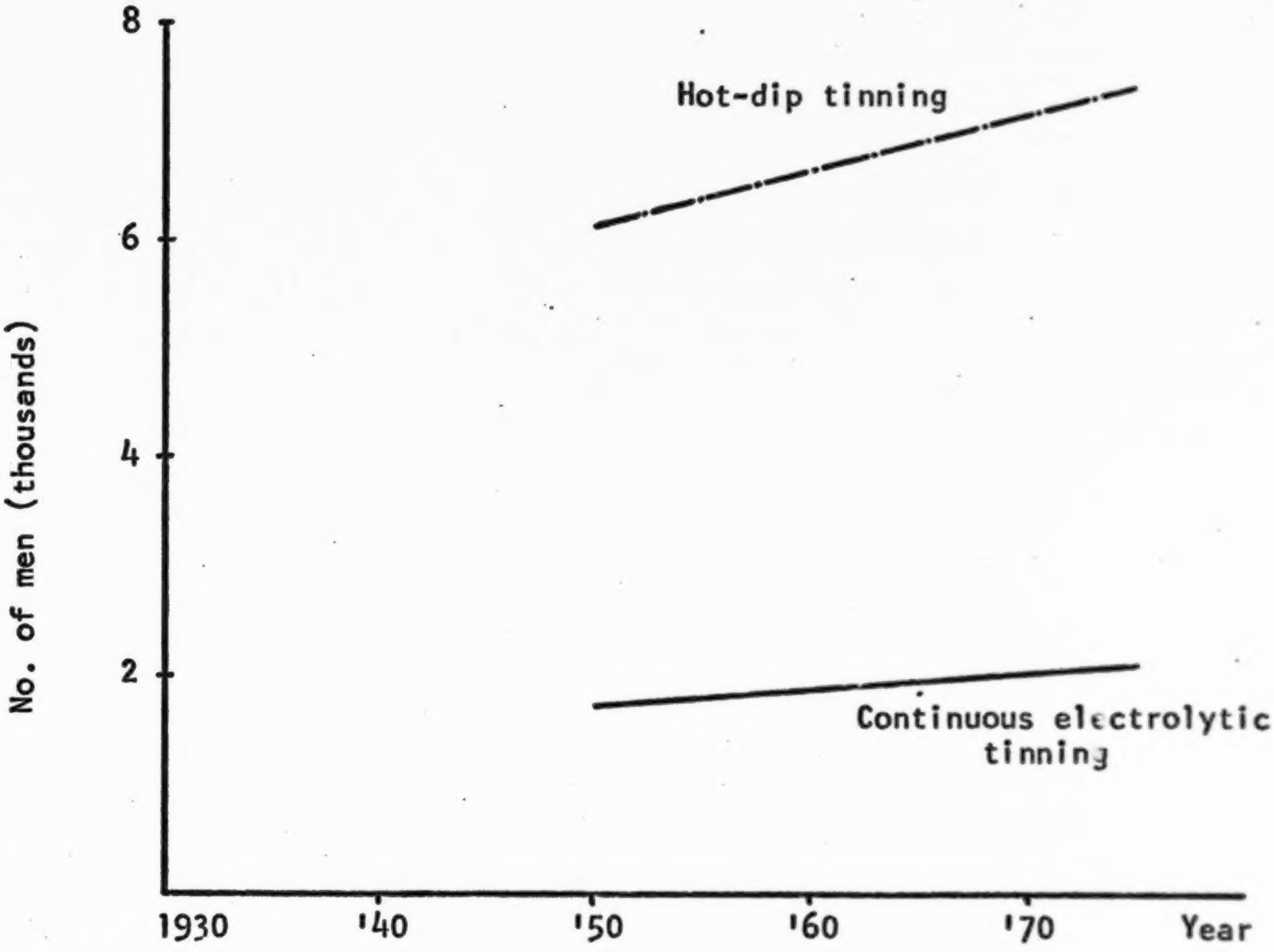

Fig. 27b: Total manpower projections based on assumption of 100% production by older or newer processes. Plotted from calculated values in Table 30.

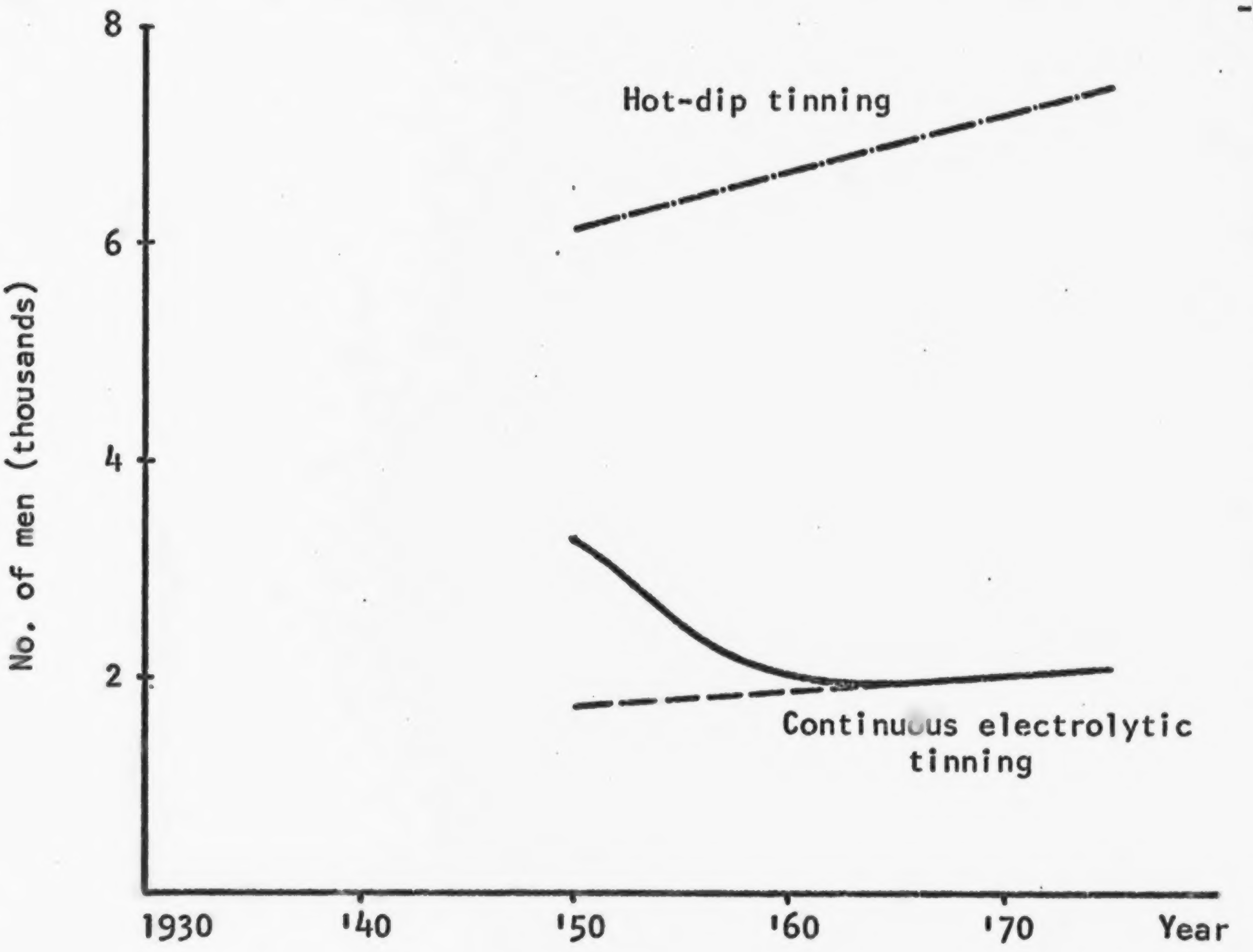

Fig. 28a: Estimated change in total manpower requirements due to introduction of new technology for tin-plating steel strip.

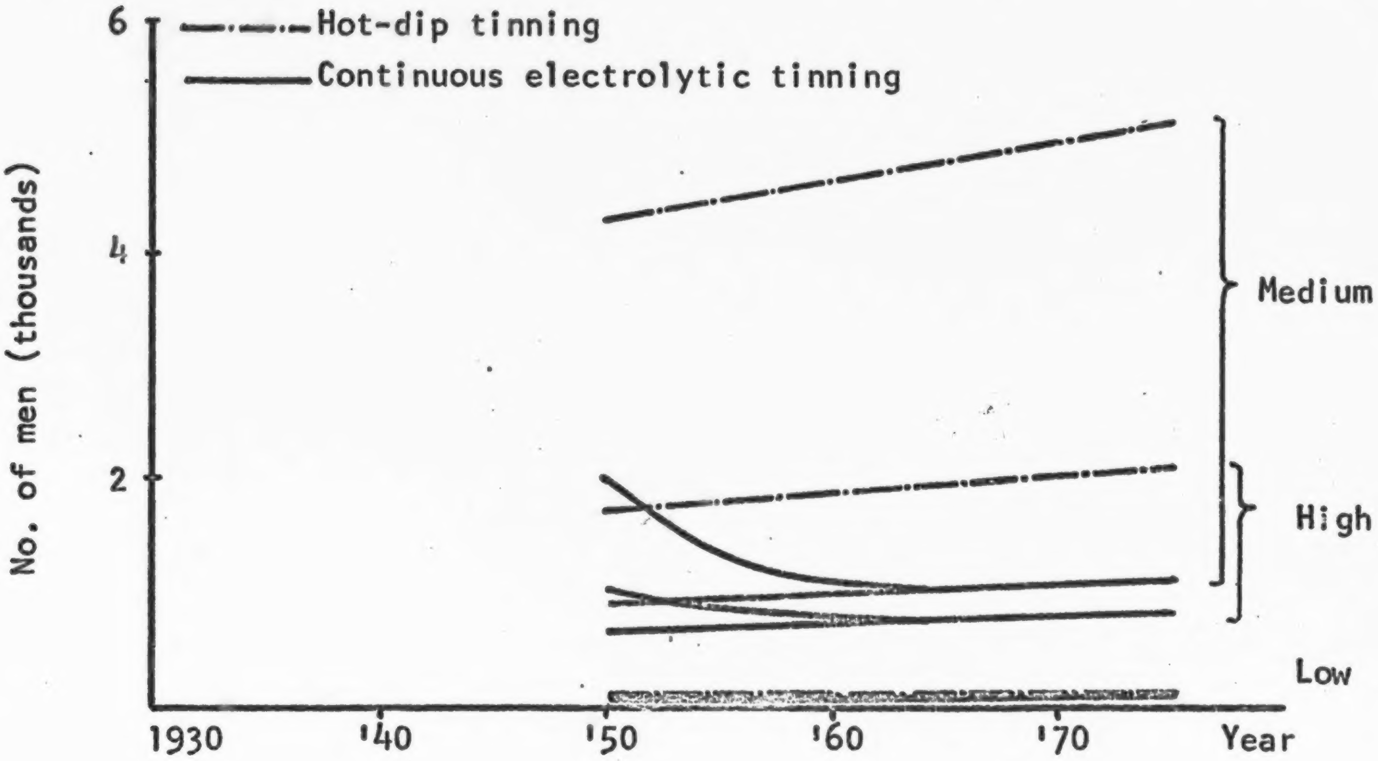

Fig. 28b: Estimated changes in requirements for manpower at different skill levels in tin-plating steel strip.

Continuous tinplating was introduced in 1937 and by 1948 more than 50% of all tinplate was made on continuous tinning lines; by 1965 the last of the old lines were on the way out. A plausible diffusion curve is shown in Figure 27a. As with galvanizing, hot-dip tinplating is very much less productive than the continuous process, and as soon as production problems were solved on the newer process, the total elimination of its predecessor was a matter of a few years only, around the late 'forties.

As will be evident from Figure 28a, the decline in total manpower requirements resulting from the displacement of the older tinplating process by the newer was steeper than in any of the cases given previously. Moreover the present rate of growth in manpower requirements, assuming no dramatic increase in demand, is so small that the peak manpower requirement of the mid 'forties will not be reached again in the foreseeable future.

Policy indications relative to annealing and coating of steel products

All three processes to which the projections attempted in Sections 6.2 and 6.3 refer have undergone radical technological changes in the last 25 years. By 1955 the new equipment and methods had not merely been adopted throughout the steel industry in the United States but had largely or completely displaced the older technologies. This substitution was associated with increases in productivity up to 271% as recorded here. In two cases out of three the concurrent increases in demand were insufficient to offset the reduced manpower requirement and there were major reductions in total manpower requirement. in some cases, and more enduring decreases in others. In all three cases the rate of increase of manpower requirement will be of small proportions given the present pattern of growth of demand. Since the total tonnage output by the three processes constitutes nearly one third of the total steel industry product volume, the reductions would have had a substantial impact on the volume of direct labor employed in the industry, even in the unlikely event that other processes remained unaffected by technological advance.

Given that the demand projections made are not too far out, the outlook for total direct labor employment on the annealing process is one of mildly increasing requirements. While there will be some increase in numbers employed at higher skill levels, there is no indication that skill shortages will limit production, since both the higher and the medium skills required have been shown to be based on more or less prolonged direct experience gained on the job itself, rather than on more extensive general education. The numbers involved appear too small to justify the creation of special training courses.

This tentative forecast might prove erroneous if further technological advances were to take place. In fact, there is some likelihood of this happening. It is reported that some steelworks are at present experimenting with a new process of annealing, the essential feature of which is that coils are treated continuously but without having to be uncoiled and recoiled. The manpower requirements of this method may turn out to be even lower than for continuous strip annealing. When this process is sufficiently well run in to make skill profile measurements, it should be possible to provide definite forecasts.

No technological advances comparable in their potential impact on productivity and employment appear to be in the offing so far as galvanizing is concerned, and the only factor that would affect the correctness of our forecast here would be a substantial and enduring rise in demand. If this does not occur the rate of increase in employment from now onwards should be slow and steady. The increase will require mainly operators in the higher skill categories; the increase should be of the order of 70 jobs per five year period and by 1975 their numbers will have risen by a factor of nearly 3, as compared with 1950. At about the same time the total number of medium-skilled will be just over half of those employed in galvanizing in 1950, though they will increase at a rate of something like 80/5 years from now onwards.

As with annealing, there seems very little danger of the industry finding itself short of skilled galvanizing operators. Length of specific experience acquired on the job is again the main factor underlying the differentiation between skill levels, and only with the most senior operators is more extensive general education needed. Again there seems to be little need for specific measures arising out of an active manpower policy.

On tinplating, finally, the prospects of employment for future applicants are poorest of all due to the great productivity gain achieved by the newer technology. This is shown partly by the steep drop in manpower requirements in Figure 28, partly by the insignificant rate at which these requirements will increase after the diffusion of the continuous tinplating technology is completed. This implies that tinplating processes in the steel industry have reached a labor-static phase as may also be said of annealing and galvanizing (see Chapter 7). If it is true that tin-plating has reached this stage, further changes in skill-profile will cease and the employment prospects for new operators with skills at any level will be nearly zero. Since the major changes were complete by the early'sixties, the labor-force in tinplating has presumably already been reduced by transfer of redundant personnel to other jobs within the steel industry.

6.4 Machining complex parts

No suitable data have been obtained from which to derive predictions of demand for the complex parts produced by conventional and numerical-control machining, so that no attempt can be made to provide manpower or skill-level projections in this case.

If demand were predictable, the data on diffusion-rates reported in the recent study by the Bureau of Labor Statistics*, together with the skill-profiles reported above, could be used to derive projections. But the demand for aerospace products of the type examined varies greatly with military needs and civil aviation development. During the period of the project, indeed, the total labor-force employed in one of the two firms studied was reported up nearly 100%, a rate of growth impossible to sustain for any length of time.

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*Ref. op. cit. page 22.

§§ CHAPTER

7. GENERALIZED CONCLUSIONS AND POLICY IMPLICATIONS

Trends in Unit Labor-requirements

Taking the four processes for which demand is stable enough to yield manpower projections together, the most striking general feature of the results is the smallness of the annual increments caused by increasing demand after the new process is established. The estimated annual increases in the total labor-force for the U.S.A. shown in Tables 27-30 are as follows:

Demand-deposit accounting	1,300	jobs/year
Annealing steel strip	38	" "
Galvanizing steel strip	31	" "
Tinplating	14	" "

Except for the first, these are of course minute relative to the total labor-force, and would almost certainly not be detectable by normal statistical analysis of gross data. Thus for practical purposes the anticipated increases in demand will have no effect on the labor-force; it would take a quite unrealistic further increase to cause perceptible changes in the labor-market conditions.

The Hypothesis of a "Labor-static Phase" of production technology

Several previous observers, among them Dobb (18) and Crossman (17) have suggested that a general trend in postwar manufacturing industry is towards a stable size of labor-force for each industry, and a consequent loosening in the relationship between employment and the volume of demand for the product.

Dobb refers to the decreased flexibility of production of heavily capitalized process-plant, which must be run at capacity to minimize overheads and hence unit costs, but does not cite empirical evidence related to manpower problems. Crossman points to the fact that employment has been stationary in such highly automated industries as electricity generation and oil refining in the period since about 1945/50 and further cites observational evidence from field studies in these and other highly mechanized industries to show that, after a certain stage of mechanization has been reached, managements tend to treat their labor-force as a fixed investment; it is assumed that the members of this labor force will remain with the company throughout their working lives and will be retrained and/or redeployed within the company as technological changes occur. This is quite a different assumption from that current in most small-batch and mass-production factories where workers are taken on or laid off according to the current state of the order book, sometimes with regular annual fluctuations in total employment but more often varying in an irregular, unpredictable manner. In many economic analyses the latter situation is assumed to be true of industry as a whole, when the volume of labor expended as an input factor of production is supposed to be proportional to the volume of output produced.

According to Crossman, the increasing fixity of the labor-force in modern industry may be traced to the disappearance of the human operator's informational (i.e., guidance and control) function with the emergence of automatic controls and other mechanized information-processing devices which replace the human senses and brain as a necessary link in the production process. That this replacement occurs can readily be verified by comparing job descriptions for any of the pairs of technologies described in Appendices to this report.

When the direct human informational functions have been fully mechanized, labor ceases to make further direct (per-unit) contribution to the production process, and per-unit labor requirements are correspondingly decreased. When an industry reaches this point, its manpower needs no longer respond to the demand for its product, neither increasing with demand during booms nor decreasing during slack periods. In effect the industry has withdrawn from the general labor-market, neither advertising vacancies nor adding to the pool of unemployed. This may be termed the "labor-static" phase of technological advance of an industry or specific process, since its labor-requirements has become a static fixed quantity.

The existence of a labor-static phase is somewhat hypothetical since no quantitative analysis of the relationship between production and employment has yet established the possibility of deciding whether a given industry or process has or has not reached this stage.

Testing the "Labor-static Phase" hypothesis

As a test of the hypothesis one may use the data presented here to ask which of the processes studied have achieved a sufficient level of mechanization to enter the "labor-static" phase. While an attempt to define a precise measure of stationarity or of labor-force elasticity related to demand would take us too far afield, it would seem that the point in question is reached either when labor-force changes become too small to detect or when continuous minor technological improvements reduce overall labor-requirement sufficiently to offset normal growth in demand.

Judging from the employment projections shown in Figures 23 through 28 and the estimated rates of employment increase cited above, all of the three steel-industry processes studied appear to have become "labor-static" or nearly so in the quite recent past. This conclusion is consistent with data on numbers of production workers given in published statistics*.

Demand-deposit accounting systems in banks appear to be nearing, but not quite to have reached, the labor-static phase. This is in large part due to the volume of direct labor still employed in customer-relations (tellers) and data-conversion (e.g., proof-machine operators). If and when further technological advance removes these functions of direct labor, the banking process too may be expected to enter a static phase.

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*Manpower Report of the President, 1965, Statistical Appendix, Table C-2, "Production or Nonsupervisory Workers in Selected Industries" - entries for Primary Metal Industries.

While suitable data on demand were not available for the production of complex metal parts, the newer (N/C) process, while more productive, is still quite labor-intensive,and the labor-force would thus be expected to respond to demand nearly as much as previously. A further technological or organizational advance permitting a single operator to spread his attention over several machines running simultaneously, or the combination of transfer-machining with numerical-control might, however, bring unit labor requirements down to the critical point. This is a technological possibility unlikely to be realized in the near future on an appreciable scale.

Since four out of the five processes studied appear to be in or near a state of minimal sensitiveness of employment to demand, and since the one partial and one (probably) total exception both evidently retain a good deal of direct human manipulation of materials or information in the operation-cycle, both the general labor-static hypothesis stated above, and Crossman's earlier analysis in terms of mechanized information-processing, appear to be upheld by the evidence presented in this report.

Generalized policy implications

Taking all the studies and projections together it seems that the general policy implications are essentially negative, i.e., no special manpower adjustments are indicated to meet likely future needs for high-level skills, while the major downward movements of manpower requirement (in steel-finishing processes and banking) have already been completed. These negative implications of the results extend also to the probable impact of increased demand caused by greater average rates of economic growth or selective changes in consumption, at least those of a conceivable magnitude. Only in the case of complex metal parts would increases in demand be likely to have a major effect on the number of jobs available.

Thus if it is permissible to generalize from the small sample of industrial processes other than the aerospace study, the size of the industrial labor-force is not likely to change greatly even assuming expanded aggregate demand.

If this view is accepted,it follows that,in so far as the objective of an active manpower policy is to maintain near-full employment of an expanding labor-force with demand growing at something like the present rate, and with the present average hours of work expended per week or per year, efforts towards increasing industrial employment are not likely to produce commensurate results. Attention should therefore be directed to other sectors of the economy.

§§§ CHAPTER

8. PROBLEMS FOR FURTHER RESEARCH

The present study has served to develop a quantitative methodology for studying manpower and skill in relation to technological change and for analytically forecasting employment by industry and skill-level. It has also provided pilot results from three distinct areas of modern industry which have traditionally employed a direct labor force of significant size. Further studies in different industries and on different types of process will greatly strengthen the confidence attaching to the conclusions on automation, skill and manpower outlined above, and the present team hopes to provide further evidence along these lines.

The present results refer only to the direct production workforce, and critics may argue that since this is a decreasing proportion of the total labor-force in advanced modern industry, the exclusion of indirect labor may falsify the picture in important respects. Again further empirical evidence would be the only proper foundation for drawing more generalized conclusions and the team hopes to pursue this line also.

Apart from these major questions requiring further factual evidence, the pilot study has served to open up a number of problem-areas where analytical investigation is needed, specifically the taxonomy of production processes and the assessment of relative levels of mechanization, the description and classification of skills, the feasibility of using historical data for cross-technology comparisons, the evaluation of demand/employment elasticity in relation to level of technology, the existence and nature of the "labor-static" phase of production technology, and so forth. These are all fit subjects for further research towards a general understanding of manpower problems in relation to technology and to general economic affairs.

* * *

REFERENCES

1. Drucker, Peter, The Practice of Management, Heineman, London, 1955.

2. Diebold, John, Automation; The Advent of the Automatic Factory, Van Nostrand, New York, 1952.

3. Killingsworth, C.C., "Automation, Jobs and Manpower", Part 5 in Nation's Manpower Revolution, 1963.

4. Bureau of Labor Statistics, U.S.D.L., "A Case Study of a Large Mechanized Bakery", Report 109 (Studies of Automatic Technology), 1956.

5. Bureau of Labor Statistics, U.S.D.L., "A Case Study of a Modernized Petroleum Refinery", Report 120 (Studies of Automatic Technology), 1957.

6. Political and Economic Planning, "Three Case Studies in Automation", London, 1957.

7. Crossman, E.R.F.W., "Automation and Skill", Department of Scientific and Industrial Research: Problems of Progress in Industry Series, No. 9, H.M.S.O., London, 1960.

8. Mann, F., and Hoffman, L.R., Automation and The Worker, Holt, New York, 1960.

9. Bright, J.R., Automation and Management, Harvard Business School, Boston, 1958.

10. Bureau of Labor Statistics, U.S.D.L., "Case Study Data on Productivity and Factory Performance", 45 reports, 1951-1955.

11. Sultan, Paul and Prasow, Paul, "The Skill Impact of Automation", in Exploring the Dimensions of the Manpower Revolution, U.S. Senate, 1964.

12. Levine, Louis, "Effects of Technological Change on the Nature of Jobs", O.E.C.D. Conference, Washington, 1964.

13. A.D. Little, Inc., "Use and Analysis of Unit Operations", Report to O.M.A.T., 1965.

14. Crossman, E.R.F.W., "European Experience with the Changing Nature of Jobs Due to Automation", O.E.C.D. Conference, Washington D.C., 1964.

15. Crossman, E.R.F.W., "Taxonomy of Automation: State of Arts and Prospects", O.E.C.D. Conference, Zurich, 1966.

16. Scheffé, H., *The Analysis of Variance, Wiley*, New York, 1959.

17. Crossman, E.R.F.W., "Automation, Skill and Manpower Predictions", Tenth O.M.A.T. Seminar on Manpower Policy and Programs, U.S.D.L., Washington D.C., 1965.

18. Dobb, M.H., *Studies in the Development of Capitalism*, Routledge, London, 1963.

APPENDICES

APPENDIX I

BANKING

Machine Aided and Computorized

Check Processing and Account Posting

APPENDIX I

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1. OUTLINE OF OLDER AND NEWER TECHNOLOGIES

The "raw materials" in demand-deposit accounting are checks paid in by customers together with credit slips, and the service performed is transfer of funds from one account to another.

Both banks treated in this report operate numerous branch offices throughout the State of California. Not all of these branch offices, however, are as yet linked to the centralized computer installation, which, in both banks, became operational in the late 50's. The "unattached" branch offices retain in all essential features the techniques and practices generally employed in banks prior to the introduction of computers; they were, therefore, taken as being representative of the older technology which can best be characterized as one of machine-aided hand operations.

The machine aids are all adaptations of standard office calculating and tabulating devices, the basic operations being sorting, transcription, posting to accounts and filing checks. After receipt by the teller, the items are proved (i.e. checked for correspondence of customer indicated debit and credit dollars) and sorted into debit (checks) and credit (deposit slips) piles: debits are further sorted into those drawn on the local system and those drawn on other branches, other banks, etc. Debits drawn on the receiving branch office and all credits are passed to the bookkeeper who posts the dollar amounts to the customer account file, calculates service charges, prepares various standard documents and cancels checks posted to accounts on a perforating machine. All credits are thereafter stored in the vaults and all debits passed on to the tellers for a final verification (call-back) and for filing; they are later mailed with monthly statements prepared by the bookkeeper and returned to customers.

There are some differences in point of detail between the newer technologies practiced by Bank A and Bank B respectively. At some stage before entry into the computer, all credit and debit items have to be encoded in magnetic ink: the newer proofing machines are therefore equipped with a special device which enables proving and encoding to be done simultaneously. Encoding takes the form of reproducing information contained in a check or deposit slip in MICR (magnetic ink character recognition) characters; it is organized into four "fields", of which three are pre-printed and the last is inserted on the proofing machine at the bottom edge of the item. This information includes 1) the American Bankers Association code and the Federal Reserve code assigned to each bank, 2) a code number identifying each branch office and the customer's account number, 3) a transaction code (Trancode) containing instructions to the computer on how to deal with the item, and 4) the dollar amount transcribed from the customer's own entry.

In Bank A the proving, encoding and some sorting are done at branch level. The pre-processed items are then microphotographed and placed into bags for dispatch, some to the Electronic Data Processing Center (all credits, all debits drawn on Bank A, account charges and amendments and summarizing documents), some to an inter-bank clearing house (other bank debits). Bank B does no pre-processing at branch level where the items are merely collected, microphotographed for record purposes, and passed on to centralized encoding stations for proving and encoding.

The EDP installations can be looked on as replacing the bookkeeper function in the older systems, though the computer processes the data supplied in many more ways than does the bookkeeper, and prints out many more documents with different breakdowns of the figures than was possible under the older technology. There are four basic components in the EDP installations, which are: 1) high-speed mechanical sorters incorporating character readers, 2) magnetic tape data files, 3) computers and data processors aided by crews of computer operators and balancers or reconcilers and 4) off-line printers. The work of the EDP Center can be visualized as proceeding, more or less simultaneously, along three distinct routes:

First route - An electro-mechanical reading head takes all magnetic ink encoded information off each item in turn and transmits it in the form of impulses to the computer which updates the relevant section of the magnetic tape file (i.e. account posting), computes service charges, etc., and produces tapes for printing out customer statements and various statistical summaries.

Second route- Reconcilers compare information sheets containing independently recorded entries, duplicating the computer inputs, with the computer outputs and, after tracing and ironing out discrepancies, feed corrections back into the computer. Account changes, new account classifications, etc. are also fed into the computer from the reconciling office.

Third route - After the information has been read off them, the checks and deposit slips are subjected to a sequence of sorts on mechanical sorters in preparation for return to customers. Most of the sorting takes place only after the reconcilers have completed their balancing so that the items due for sorting are readily available to them when needed.

A slight variant exists again between the two banks in the treatment of items that have either been processes to file or are being returned for corrections or further consideration. In Bank A all items are returned to the originating branch offices, where the good checks are cancelled ("paid") and filed, returned checks are authorized or re-directed to customers and supporting documentation is placed on file. In Bank B the good checks, as well as printed statements, go to an Account Servicing Center where they are held on file for final dispatch to customers; returned checks and some standard statistical documents are sent back to branches directly, the former for authorization, the latter for the branch file.

2. DESCRIPTIVE CHARTS OF CHECK PROCESSING AND ACCOUNT POSTING OPERATIONS, BANKS A & B

The charts in this section list and describe in consecutive columns:

The Operations:	A discrete block of related tasks and activities.
The Operators:	Job title of the operator who normally performs some or all of the activities.
The Equipment used:	Major pieces of machinery used in the operations defined in column 1.
The Method:	Usual procedures for performing the operations.
The Mode of Operation and Control:	The main perceptual and motor aspects of the operator's actions.
The Level of Mechanization:	The figures are based on a scale constructed by J.R. Bright and describe the degree of functional autonomy built into the equipment used. A copy of this scale, giving definitions of the level numbers, precedes the charts.

Initiating Source	Type of Machine Response		Power Source	Level Number	LEVEL OF MECHANIZATION
From a variable in the environment	Responds with action	Modifies own action over a wide range of variation.	Mechanical (Nonmanual)	17	Anticipates action required and adjusts to provide it.
				16	Corrects performance while operating.
				15	Corrects performance after operating.
		Selects from a limited range of possible prefixed actions.		14	Identifies and selects appropriate set of actions.
				13	Segregates or rejects according to measurement.
				12	Changes speed, position, direction according to measurement signal.
	Responds with signal			11	Records performance.
				10	Signals preselected values of measurement. (Includes error detection)
				9	Measures characteristic of work.
				8	Actuated by introduction of work piece or material.
	Fixed within the machine			7	Power Tool System, Remote Controlled.
				6	Power Tool, Program Control (sequence of fixed functions).
				5	Power Tool, Fixed Cycle (single function).
From man	Variable			4	Power Tool, Hand Control.
				3	Powered Hand Tool.
			Manual	2	Hand Tool.
				1	Hand.

SEVENTEEN LEVELS OF MECHANIZATION AND THEIR RELATIONSHIP

TO POWER AND CONTROL SOURCES

(Reproduced from J.R. Bright, Automation and Management,
Boston: Harvard University, 1958, Exhibit 4-2, pg. 45)

Operation	Operator	Equipment Used	Method	Mode of Operation and Control	Level of Mechanization (J.R. Bright scale)
Reception and collation	Teller	Adding Machine	Accepts checks, deposit slips and cash from customers. Verifies amount on deposit slip, signature, up-dates passbook. Sorts deposit tickets, withdrawal tickets, cash slips etc. Balances teller's batch.	Visual checking, mental calculations, occasional resort to adding machine.	1,5
Proving deposit totals against checks; listing of items, sorting "on us"/ other items.	Proof Machine Operator	Proof machine (key operated adding/listing machine)	Lists debits and credits and sorts items into compartments. Verifies correspondence of debits and credits for each transaction. Makes adjusting entries when necessary. Totals and recapitulates tapes for each compartment.	Manual item and data input, machine processing.	1,5
Sorting by account numbers	Paying and Filing Clerk or Bookkeeper	(Sorting tray)	Sorts checks into sections comprised of about 100 account numbers. Sequences checks within each section. Sorts deposit slips.	Manual processing	1
Recording items on microfilm	Paying and Filing Clerk or Bookkeeper	Microfilm machine	Feeds checks into machine	Manual item input, automatic operation.	5
Posting debits and credits to customers accounts; calculating balance, listing of items entered, posting in general ledger.	Bookkeeper	Bookkeeping machine (key-operated special purpose calculating and printing machine)	Posts debits and credits and up-dates balance on account ledger card. Totals bookkeeper's register and balances with consolidated blotter. Periodically determines and posts service charges. Prepares returned items for authorization.	Manual item and data input, machine processing.	5

(continued)

A1: MACHINE AIDED CHECK PROCESSING AND ACCOUNT POSTING

Operation	Operator	Equipment Used	Method	Mode of Operation and Control	Level of Mechanization (J.R. Bright scale)
"Paying" checks, i.e. cancellation by perforation.	Paying and Filing Clerk	Perforator	Passes checks through perforator for "payment" and dating.	Manual item input, automatic operation.	5
Verifying correctness of bookkeeper's entries.	Teller	(Adding machine)	Compares checks with listings in individual account ledger sheets (each teller responsible for 100 - 200 accounts).	Visual checking, manual processing.	5
Verifying signatures; filing by account number.	Teller	- -	Compares signatures with specimen on card; files checks by account number.	Visual checking, manual processing.	1
Assembling statements and checks, mailing to customer (monthly)	Payment and Filing Clerk or Teller	Postage Meter machine	Merges checks with copy of individual account ledger sheet, inserts in envelope, seals, passes through postage meter machine, places in mail bag.	Manual item handling and input, automatic operation	1,5

(concluded)

A1: MACHINE AIDED CHECK PROCESSING AND ACCOUNT POSTING

BRANCH OFFICE

Operation	Operators	Equipment Used	Method	Mode of Processing		Level of Mechanization (J.R. Bright scale)
				Materials	Information	
Reception and Collation	Teller	Adding machine Account number encoder	Accepts checks, deposit slips and cash from customer. Verifies deposit slip cash amount, signatures, updates passbook. Sorts deposit tickets, withdrawal tickets, cash slips, etc. Balances all teller's transactions.	Direct Manipulation	Unaided mental arithmetic, etc. + Adding machine	1,5
Encoding, Proofing, Sorting	Proof Machine Operator	Proof machine and MICR encoder	Lists debits and credits, encodes amount and sorts into compartments. Verifies correspondence of debits and credits for each transaction. Makes adjusting entries when necessary. Totals and recapitulates tapes for each compartment.	Direct manipulation; pockets used to segregate types of item.	Reading and keying by operator; proof machine calculates and print-lists; some mental arithmetic.	1,5
Microfilming, Assembling and Bagging	Proof Machine Operator	Microfilm machine	Runs items through microfilm processor. Assembles items into batches. Prepares and attaches batch header slip. Places batch in proper mail bag.	Direct manipulation + Power-drive	Automatic copy-making	1,5
Transport to EDP Center	Messenger		Picks up bags of items at branch and delivers to EDP Center.	Powered vehicle, hand-carrying.	---	4

EDP CENTER

Receiving and Distributing Supporting documents	Preparation and Distribution Clerks		Separates work, prepares items for distribution and distributes supporting documents.	Direct manipulation, trays used for segregating material.	---	1
Preparation of items for processing	Preparation and distribution clerks, Senior Sorter operators	Jogger	Inserts batch separator and identification cards. Scans items for orientation, condition, etc. Places items in jogger to align edges. Moves items to Reader/Sorter machine.	Direct manipulation + Powered jogger	---	1,5
Reading information into computer and sorting items (Entry run) ②①③	Senior sorter Operators	Reader/Sorter machine Computer, transmission lines	Sets machine for proper sorting. Feeds items into machine which transmits information to computer over transmission lines (follow broken line ①) and sorts readable and non readable items into separate pockets. Items are removed from pockets by hand and placed in trays in original sequence. Readable checks are moved to offline sorter (follow line ②) and non-read items to reconcilement (follow line ③) office. Unjams and restarts machine when necessary.	Hand feeding of batches; powered transport of items past reading head and through sorting gates; hand unloading from "pockets".	Automatic reading of MICR characters; magnetic tape storage; results used to direct materials, under program control.	14

A 2: COMPUTERIZED CHECK PROCESSING

(continued)

Operation	Operators	Equipment Used	Method	Mode of Processing		Level of Mechanization (J.R. Bright scale)
				Materials	Information	
Listing misreads and discrepant items	(Computer Operators) Printer Operators Reconciler Clerks	Printer Computer Adding machine	Computer prepares magnetic tape listing of all items read in with calculated sub-totals and batch-totals; listed on off line printer; reconciler lists rejects and non reads; calculates totals of nonreads.	Direct manipulation of already segregated nonread items.	Item listing under program control; printout to provide visually readable record; visual reading keypunching to list items not readable by computer; mechanical computation of totals under manual control.	1,5,14
Reconciling Proofing Recapping	Reconciler Clerk Proof-machine Operators Utility Clerks	Adding machine Account-number encoder Proof machine	Verifies batch totals. Cross-checks out-of-balance batches to locate and adjust errors and to resolve differences. Makes adjustments, corrections and disposition of rejected and non-read items. Lists balanced batch totals, proves and sorts reconciled batches and prepares debits and credits for further processing. Prepares consolidated recap. Balances work for entire center.	---	Reading and keying by operator(s); locating and comparisons of appropriate figures; decision on procedure for locating source of discrepant totals.	1,5
Preparing record changes	Flexotypist	Flexowriter	Types account change information onto paper or magnetic tape for later entry into computer.	---	Visual reading, keying; machine writes visual and/or machine-readable data.	5
Account updating	Computer Operators Preparation and Distribution Clerks	Printer Computer Bursting machines, collators	Loads data tapes and program tapes onto computer. Operates computer to process data in sequence as per standard operating schedules. (Machine posts and updates accounts, computes service charges, makes amendments to accounts). Reports and documents for use of Center and for next phase of operation printed on machine. Bursts, collates and distributes reports and documents to appropriate trays and bags.	---	Data on magnetic entry tapes sorted in stages into account number order; data used to update entries on magnetic tape account file; discrepant items listed on mag.tape; data edited and formated for printing, all under program control.	14

(continued)

A 2: COMPUTERIZED CHECK PROCESSING

②

Operation	Operators	Equipment Used	Method	Mode of Processing		Level of Mechanization (J.R. Bright scale)	
				Materials	Information		
Reading and Sorting of corrected information.	Senior Sorter Operators	Reader/Sorter machine Reader to computer transmission lines.	TAPES: Loads previously prepared paper or magnetic tapes with corrections to machine loading head, which transmits information to computer-memory. CHECKS: Performs same activities as for original run.	Hand feeding of batches and paper tapes; powered transport in machine, hand unloading.	Machine reading of MICR and punched-tape characters, editing and sorting under program control.	14	EDP CENTER
→ Off-line sorting of items.	Junior Sorter Operator	Reader-Sorter (machine operated off-line, i.e. not under computer control)	Sets machine for sorting on first digit and feeds checks into Sorting machine, which reads digit and sorts into proper pocket. Removes checks from pockets, feeds back into sorter and repeats steps 1 to 3 until checks have been sorted on all digits. Places sorted checks into appropriate bags and bins.	Hand feeding of batches into sorter; hand unloading; powered transport through sorting-machine; hand-clearing of jammed items.	Mode of operation hand-set; machine reads MICR characters and actuates sorting gates.	5	
Receiving and Processing information and items returned to branch.	Proof-machine Operator Audit Clerks	Proof machine Adding machine	Receives and processes non-read checks. Receives and processes checks for return to customer (insufficient funds). Authorizes payment of items. Receives and files branch reports.	Direct manipulation	Visual reading and keying; some arithmetic operations; decisions based on collation of data; some typing.	1,5	ACCOUNT SERVICES CENTER
"Payment", filing of checks and mailing of statements.	Returned items Clerk Paying and Filing Clerk Statement Clerk	Perforator Adding machine Postage meter machine	Receives checks, verifies signatures, perforates checks ("payment") and files for subsequent return to customer. Merges checks and account statements (monthly) and prepares for mailing to customer.	Direct manipulation	Visual reading, comparing.	1,5	

(concluded)

A 2: COMPUTERIZED CHECK PROCESSING

Operation	Operator	Equipment Used	Method	Mode of Operation and Control	Level of Mechanization (J.R. Bright scale)
Reception and collation.	Teller	Adding Machine	Accepts checks, deposit slips and cash from customers. Verifies amount on deposit slip, signature, up-dates pass book. Sorts deposit tickets, withdrawal tickets, cash slips etc. Balances teller's batch.	Visual checking, mental calculations, occasional resort to adding machine.	1, 5
Proving deposit totals against checks; listing of items, sorting "on us"/ other items.	Proof Machine Operator	Proof machine (key operated adding/listing machine)	Lists debits and credits and sorts items into compartments. Verifies correspondence of debits and credits for each transaction. Makes adjusting entries when necessary. Totals and recapitulates tapes for each compartment.	Manual item and data input, machine processing.	1, 5
Sorting by account numbers.	Bookkeeper	(Sorting tray)	Sorts checks into section comprised of about 100 account numbers. Sequences checks within each section. Sorts deposit slips.	Manual processing.	1
Recording items on microfilm.	Bookkeeper	Microfilm machine	Feeds checks into machine.	Manual item input, automatic operation.	5
Posting debits and credits to customer's accounts; calculating balance, listing of items entered; posting in general ledger.	Bookkeeper	Bookkeeping machine (key-operated special purpose calculating and printing machine)	Posts debits and credits and updates balance on account ledger card. Totals bookkeeper's register and balances with consolidated blotter. Periodically determines and posts service charges. Prepares returned items for authorization.	Manual item and data input, machine processing.	5

(continued)

B1: MACHINE AIDED CHECK PROCESSING AND ACCOUNT POSTING

Operation	Operator	Equipment Used	Method	Mode of Operation and Control	Level of Mechanization (J.R. Bright scale)
"Paying" checks, i.e. cancellation by stamp.	Bookkeeper	Stamping machine	Passes checks through stamping machine for "payment" and dating.	Manual item input, automatic operation	5
Verifying correctness of bookkeeper's entries	Teller	(Adding machine)	Compares checks with listings in individual account ledger sheets. (Each teller is responsible for 100-200 accounts)	Visual checking, manual processing.	1
Verifying signatures; filing by account number.	Teller	- - - -	Compares signature with specimen on card. Files checks by account number.	Visual checking, manual processing.	1
Assembling statements; mailing to customer (monthly)	Bookkeeper	Postage meter machine	Merges checks with copy of individual account ledger s sheet, inserts in envelope, seals, passes through postage meter machine, places in mail bag.	Manual item handling and input, automatic operation	1, 5

(concluded)

BRANCH OFFICE

ENCODING CENTER

Operation	Operators	Equipment Used	Method	Mode of Processing		Level of Mechanization (J.R. Bright scale)
				Materials	Information	
Reception and collation	Teller	Adding machine Account Number Encoder	Accepts checks, deposit slips and cash from customer. Verifies deposit slip cash amount, signature, updates passbook. Sorts deposit tickets, withdrawal tickets, cash slips, etc. Balances cash transactions.	Direct manipulation	Unaided mental arithmetic, etc. and adding machine.	1,5
Microfilming Assembling and Bagging	Branch clerks Utility clerks	Microfilm machine	Runs items through microfilm processor. Assembles items into batches. Prepares and attaches batch header slip. Places batch in proper mail bag.	Direct manipulation + Power-drive	Automatic copy-making	1,5
Transport to Encoding Center	Mail clerks	- -	Picks up bags of items at branch and delivers to Encoding Center	Powered vehicle, hand carrying	---	4
Reception and distribution of items	Junior Clerks Senior Clerks Ass't. Section Supervisors	Scale	Records arrival time and weight of items arriving from branches (weight indicated volume of items). Allocates batches of items.	Direct manipulation	---	1
Proofing and Encoding	Proof Machine Operators Junior Clerks	Proof Machines and MICR Encoders	Lists debits and credits on machine. Verifies correspondence of debits and credits for each transaction. Makes adjusting entries when necessary.	Direct manipulation	Reading and keying by operator; proof machine calculators and print-lists.	1,5
Assembling items	Junior Clerks	Adding machine	Separates supporting documents. Assembles items into blocks. Verifies correspondence of debits and credits for each block. Writes up differences, if any. Balances tellers' transactions.	Direct manipulation	Mental comparison of appropriate figures; some mental arithmetic and use of adding machine.	1,5
Transport items to Data Processing Center	Junior Clerks		Delivers items and supporting documents to appropriate locations in EDP Center.	Hand-carrying	---	1

(continued)

3 mej.

Operation	Operators	Equipment Used	Method	Mode of Processing		Level of Mechanization (J.R. Bright scale)
				Materials	Information	
Preparation of items for processing	Assemblers Computer Operators	Jogger	Inserts block separator and identification cards. Scans items for orientation, condition, etc. Places items in jogger to align edges. Moves items to Reader/Sorter machine.	Direct manipulation + Powered Jogger	---	1,5
Reading information into computer and sorting items ③ ① ②	Computer Operators	Reader/Sorter Machine Computer transmission lines	Sets machine for proper sorting. Feeds items into machine which transmits information to computer over transmission lines.(follow broken line①) and sorts readable and non-readable items into separate pockets. Items are removed from pockets by hand and placed in trays in original sequence. Readable checks are moved to off-line sorter (follow line②) and non-readable items to reconcilement (follow line③) office. Adjusts and restarts machine when necessary.	Hand feeding of blocks; powered transport of items past reading head and through sorting gates; hand unloading from "pockets". Rand cleaning of jammed items	Automatic reading of MICR characters; magnetic tape storage; results used to direct materials under program control.	14
Listing Dollar Information	Computer Operators	Printer and Multiple Lister Computer Adding Machine	Operates computer and printer to list individual checks, sub-totals and block totals. Operates adding machine to list rejected items.	Direct manipulation of already segregated items.	Item listing under program control; printout to provide visually readable record, visual reading by punching to list items not readable by computer, mechanical computation of totals under manual control.	1,5,14
Reconciling, Proofing, Recapping, Reclaiming	Junior Reconcilers Senior Reconcilers Senior Working Supervisors	Adding machine Account Number Encoder	Verifies batch totals. Cross checks out-of-balance blocks to locate and adjust errors and to resolve differences. Makes adjustments, corrections and disposition of rejected and non-read items. Lists balanced block totals, proves and sorts reconciled blocks and prepares debits and credits for further processing. Prepares consolidated recap.	---	Reading and keying by operators; locating and comparison of appropriate figures; decision on procedure for locating source of discrepant totals.	1,5

①②

(continued)

B2: COMPUTERIZED CHECK PROCESSING

① ②

Operation	Operators	Equipment Used	Method	Mode of Processing		Level of Mechanization (J.R. Bright scale)
				Materials	Information	
Reconciling, Proofing, Recapping, Reclaiming (continued)		------	Balances work for entire center. Processes checks to be returned to endorser (insufficient funds), received from branch offices.	- -	see above	1,5
Prepare Record Changes	Junior Department Clerks	Flexowriter	Types account change information onto paper or magnetic tape for later entry into computer	---	Visual reading, keying; machine writes visual or machine readable data.	5
Account Updating	Computer Operator Department Clerk	Printer Computer Bursting machines Collators	Loads data tapes and programs tapes onto computer. Operates computer to process data in sequence as per standard operating schedules. Machine posts and updates accounts, computer service charges, makes amendments to accounts. Reports and documents for use of center and for next phase of operation printed on machine. Manual bursting collation and distribution of reports to appropriate bins and bags.	---	Data on magnetic entry tapes sorted in stages into account number order; data used to update entries on magnetic tape account file, discrepant items listed on mag.tape; data edited and formated for printing; all under program control.	14
Reading and sorting of corrected information	Computer Operator	Reader/Sorter machine Reader to computer transmission lines.	TAPES: Loads previously prepared paper or magnetic tapes with corrections to machine reading head, which transmits information to computer memory. CHECKS: Performs same activities as for original run.	Hand feeding of blocks and paper tapes; powered transport in machines; hand unloading.	Machine reading of MICR and punched tape characters; editing and sorting under program control.	14
Off line sorting of items	Fine Sort Operators Department Clerks	Reader/Sorter machine (operated off-line, i.e., not under computer control)	Sets machine for sorting on first digit and feeds checks into sorting machine which reads digit and sorts into proper pocket. Operator removes checks from pocket, feeds back into sorter and repeats above steps until checks have been sorted on all digits. Places sorted checks into appropriate bags and bins.	Hand feeding of blocks into sorter; hand unloading; powered transport through sorting machine; hand clearing of jammed items.	Mode of operation hand-set; machine reads MICR characters and actuates sorting gates.	5

(continued)

B 2: COMPUTERIZED CHECK PROCESSING

Operation	Operators	Equipment Used	Method	Mode of Processing		Level of Mechanization (J.R. Bright scale)	
				Materials	Information		
Receiving and Processing of items returned by EDP Center	Working Supervisors Department Clerks	Typewriter Telephone	Receives and processes non-read checks. Receives lists of checks returned due to insufficient funds. Obtains authorization for payment of these checks or refusal and phones decisions to Account Service Center (where all checks are held). Receives, distributes and files branch documents and reports received from computer.	Direct manipulation	Visual reading and keying; some arithmetic operations; decisions based on collation of data; some typing. Verbal transmission on to distant location.	1,5	BRANCH OFFICE
"Payment", filing of checks and mailing of statements.	Working Supervisors Department Clerks	Stamping machine Automatic filing units Postage Meter machine Telephone	Receives checks, verifies signatures, pays and files checks, merges checks with statements (monthly) and prepares for mailing. Provides account information to branches on request (by phone). Pulls non-authorized returned checks from files and sends to reclamation department for mailing to endorser.	Direct manipulation	Visual reading, comparing; decisions based on information received from branch. Verbal transmission in response to requests.	1,5	ACCOUNT SERVICES CENTER

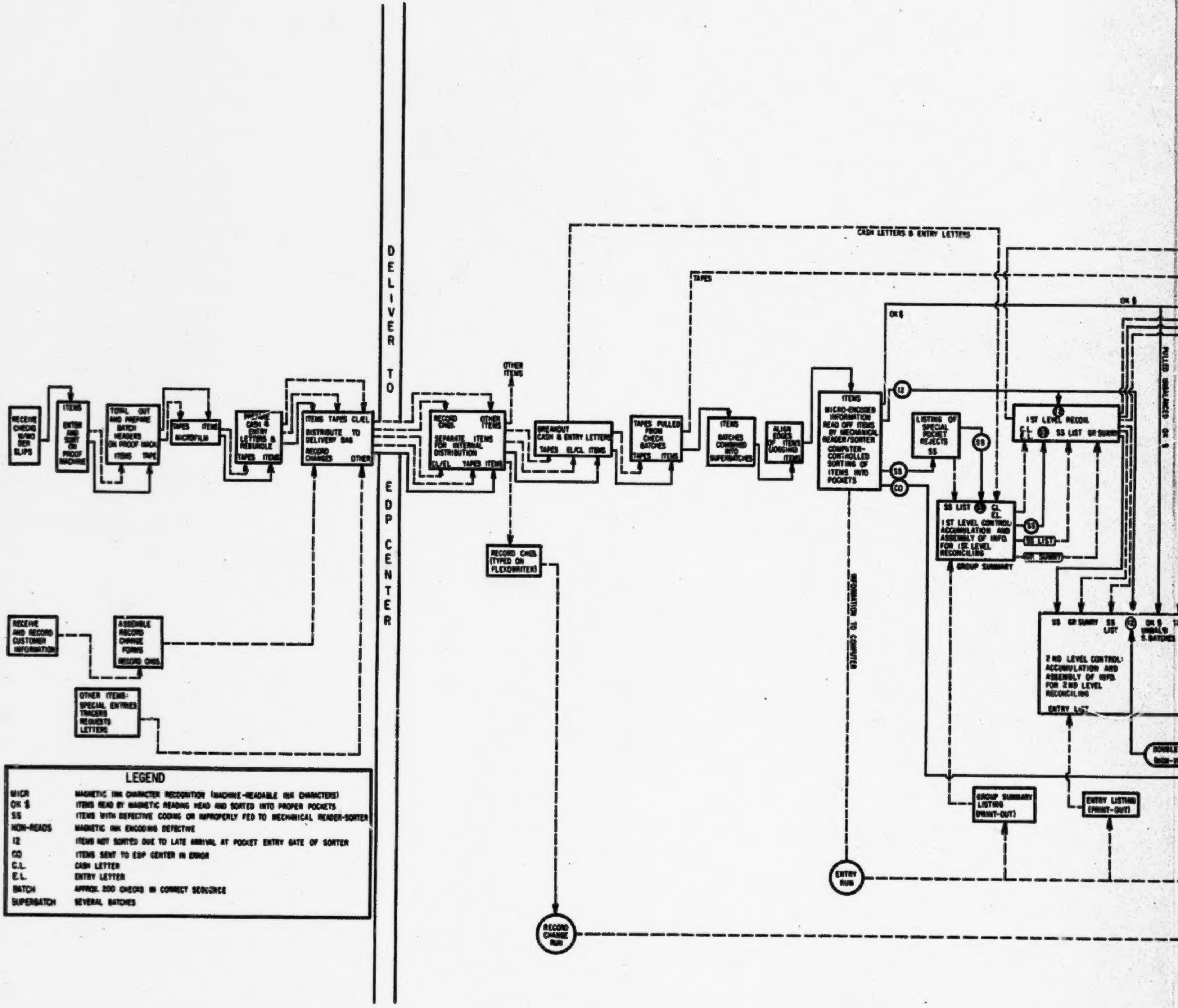
B 2: COMPUTERIZED CHECK PROCESSING

(concluded)

3. PROCESS CHART OF COMPUTORIZED CHECK PROCESSING AND ACCOUNT POSTING IN BANK A

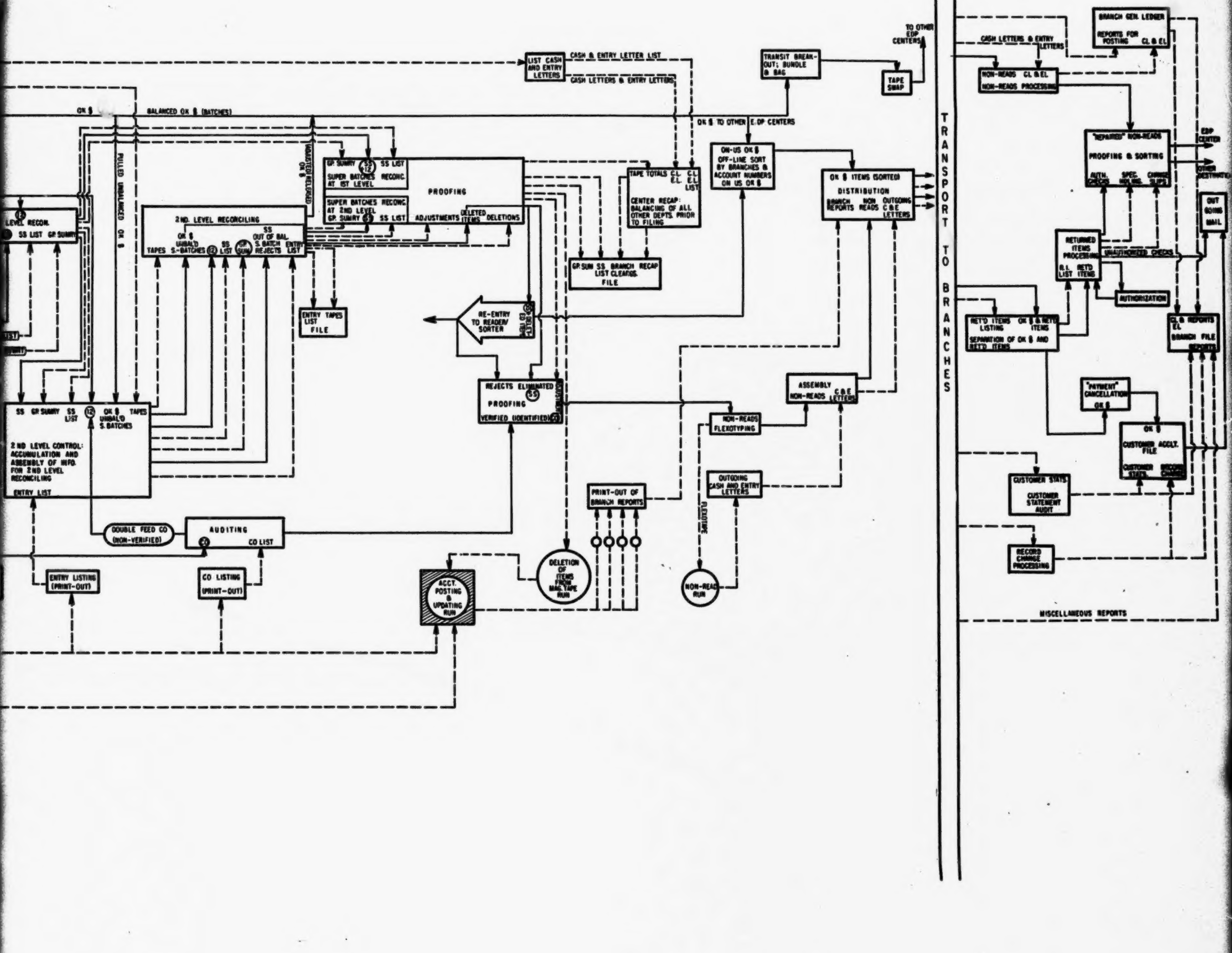
This section contains a detailed process chart of the flow of material and information from the reception of the items by the teller to the final returning of the checks to the customer in the computorized system of Bank A. The solid flow lines represent items (checks and deposit slips), the broken lines - information transferred from these items (e.g. onto other documents, onto magnetic tape, into the computer, etc.), or information contained in documents other than checks and deposit slips. Machine aided hand processing activities are shown by blocks, while circles represent computer processing.

Although the chart represents the activities and flow for Bank A, it is also descriptive of the computorized technology in Bank B. Virtually the same functions are performed with a slight alteration in sequence at some points.


RECEIVE CHECKS W/WO DEP SLIPS
ITEMS
ENTER AND SORT ON PROOF MACHINE
TOTAL OUT AND PREPARE BATCH HEADERS ON PROOF MACH
ITEMS
TAPE
TAPES
ITEMS
MICROFILM
CASH & ENTRY LETTERS & REBUNDLE
TAPES
ITEMS
ITEMS
TAPES
CL/EL
DISTRIBUTE TO DELIVERY BAG
RECORD CHANGES
OTHER
DELIVER TO EDP CENTER
RECEIVE AND RECORD CUSTOMER INFORMATION
ASSEMBLE RECORD CHANGE FORMS
RECORD CHGS.
OTHER ITEMS: SPECIAL ENTRIES TRACERS REQUESTS LETTERS
OTHER ITEMS
RECORD CHGS.
OTHER ITEMS
SEPARATE ITEMS FOR INTERNAL DISTRIBUTION
CL/EL
TAPES
ITEMS
RECORD CHGS. (TYPED ON FLEXOWRITER)
RECORD CHANGE RUN
BREAKOUT CASH & ENTRY LETTERS
TAPES
EL/CL
ITEMS
CASH LETTERS & ENTRY LETTERS
TAPES
TAPES PULLED FROM CHECK BATCHES
TAPES
ITEMS
ITEMS
BATCHES COMBINED INTO SUPERBATCHES
ALIGN EDGES OF ITEMS (JOGGING)
ITEMS
ITEMS
MICRO-ENCODED INFORMATION READ OFF ITEMS BY MECHANICAL READER/SORTER
COMPUTER-CONTROLLED SORTING OF ITEMS INTO POCKETS
OK $
12
SS
CO
INFORMATION TO COMPUTER
ENTRY RUN
LISTING OF SPECIAL POCKET REJECTS
SS
SS
SS LIST
CL
EL
1 ST LEVEL CONTROL: ACCUMULATION AND ASSEMBLY OF INFO. FOR 1ST LEVEL RECONCILING
SS
SS LIST
GP. SUMRY
GROUP SUMMARY
1 ST LEVEL RECON.
12
C.L.
E.L.
SS LIST
GP SUMRY
OK $
PULLED UNBALANCED OK $
SS
GP SUMRY
SS LIST
12
OK $ UNBAL'D S. BATCHES
2 ND LEVEL CONTROL: ACCUMULATION AND ASSEMBLY OF INFO. FOR 2 ND LEVEL RECONCILING
ENTRY LIST
DOUBLE
GROUP SUMMARY LISTING (PRINT-OUT)
ENTRY LISTING (PRINT-OUT)

LEGEND

MICR	MAGNETIC INK CHARACTER RECOGNITION (MACHINE-READABLE INK CHARACTERS)
OK $	ITEMS READ BY MAGNETIC READING HEAD AND SORTED INTO PROPER POCKETS
SS	ITEMS WITH DEFECTIVE CODING OR IMPROPERLY FED TO MECHANICAL READER-SORTER
NON-READS	MAGNETIC INK ENCODING DEFECTIVE
12	ITEMS NOT SORTED DUE TO LATE ARRIVAL AT POCKET ENTRY GATE OF SORTER
CO	ITEMS SENT TO EDP CENTER IN ERROR
C.L.	CASH LETTER
E.L.	ENTRY LETTER
BATCH	APPROX. 200 CHECKS IN CORRECT SEQUENCE
SUPERBATCH	SEVERAL BATCHES


LEVEL RECON.
12
SS LIST
GP. SUMRY
OK $
BALANCED OK $ (BATCHES)
PULLED UNBALANCED OK $
ADJUSTED RELEASED OK $
LIST CASH AND ENTRY LETTERS
CASH & ENTRY LETTER LIST
CASH LETTERS & ENTRY LETTERS
GP. SUMRY
SS 12
SS LIST
SUPER BATCHES RECONC. AT 1ST LEVEL
SUPER BATCHES RECONC. AT 2ND LEVEL
GP. SUMRY
SS
PROOFING
ADJUSTMENTS
DELETED ITEMS
DELETIONS
2ND. LEVEL RECONCILING
TAPES
OK $ UNBAL'D S.-BATCHES
12
SS LIST
GP. SUM
SS OUT OF BAL. S. BATCH REJECTS
ENTRY LIST
ENTRY TAPES LIST FILE
RE-ENTRY TO READER/SORTER
DELETED ITEMS
REJECTS ELIMINATED
SS
PROOFING
VERIFIED (IDENTIFIED)
CO
ADJUSTED
SS
GP. SUMRY
SS LIST
12
OK $ UNBAL'D S. BATCHES
TAPES
2ND LEVEL CONTROL: ACCUMULATION AND ASSEMBLY OF INFO. FOR 2ND LEVEL RECONCILING
ENTRY LIST
DOUBLE FEED CO (NON-VERIFIED)
AUDITING
CO
CO LIST
ENTRY LISTING (PRINT-OUT)
CO LISTING (PRINT-OUT)
ACCT. POSTING & UPDATING RUN
DELETION OF ITEMS FROM MAG. TAPE RUN
PRINT-OUT OF BRANCH REPORTS
TAPE TOTALS C.L. E.L.
C.L. E.L. LIST
CENTER RECAP: BALANCING OF ALL OTHER DEPTS. PRIOR TO FILING
GP. SUM SS BRANCH RECAP LIST CLEARGS. FILE
TRANSIT BREAK-OUT; BUNDLE & BAG
TAPE SWAP
TO OTHER EDP CENTERS
OK $ TO OTHER E.DP CENTERS
ON-US OK $
OFF-LINE SORT BY BRANCHES & ACCOUNT NUMBERS ON US OK $
OK $ ITEMS (SORTED)
DISTRIBUTION
BRANCH REPORTS
NON READS
OUTGOING C & E LETTERS
ASSEMBLY
NON-READS
C & E LETTERS
NON-READS FLEXOTYPING
OUTGOING CASH AND ENTRY LETTERS
FLEXOTAPE
NON-READ RUN
TRANSPORT TO BRANCHES
CASH LETTERS & ENTRY LETTERS
BRANCH GEN. LEDGER
REPORTS FOR POSTING
CL & EL
NON-READS CL & EL
NON-READS PROCESSING
"REPAIRED" NON-READS
PROOFING & SORTING
AUTH. CHECKS
SPEC. HOLDS.
CHANGE SLIPS
EDP CENTER
OTHER DESTINATION
OUT GOING MAIL
RETURNED ITEMS PROCESSING
R.I. LIST
RET'D ITEMS
UNAUTHORIZED CHECKS
AUTHORIZATION
RET'D ITEMS LISTING
OK $ & RET'D ITEMS
SEPARATION OF OK $ AND RET'D ITEMS
CL & REPORTS EL
BRANCH FILE
REPORTS
"PAYMENT" CANCELLATION
OK $
OK $
CUSTOMER ACCT. FILE
CUSTOMER STATS.
RECORD CHANGE
CUSTOMER STATS
CUSTOMER STATEMENT AUDIT
RECORD CHANGE PROCESSING
MISCELLANEOUS REPORTS

4. METHOD OF DERIVING SKILL LEVEL VALUES FROM JOB EVALUATION SCHEMES

Bank A

The job evaluation scheme has been in operation for many years and has not been changed when EDP was introduced. It is conceived in terms of the following factors to each of which corresponds a range of "points":

MENTAL EFFORT

SKILL

Responsibility

Physical effort

Working conditions

Only the first two factors were considered in the present study. Mental effort is defined as:

> "The mental activity required to do the jobs. It consists of complexity, difficulty, novelty, pressure, and variety which manifest themselves in the alertness, adaptation and thinking required for the job."

It carries 24 discrete point values in the range 19 to 392.

Skill is defined as:

> "The total knowledge, experience and training required to obtain the mental or physical ability for the minimum level of satisfactory performance."

This factor carries 20 discrete point values in the range 33 to 392.

The Mental Effort and the Skill scores allocated to each job were summed to yield the total skill score used in the analysis.

Bank B

This bank has dropped its job evaluation scheme a few years ago and substituted a form of job ranking method which is felt to provide more flexibility. The Personnel Department, however, agreed to rate all jobs considered in this report on the now superseded scheme which consisted of six separate factors:

COMPLEXITY OF DUTIES

PREPARATION FOR THE JOB

Responsibility for operations, policy, money, etc.

Contact with others

Supervision exercised

Working conditions

Again the first two factors only were used. Complexity of duties is specified by the definition

> "The difficulty of decisions and judgment".

It carries 14 possible discrete point values in the range 21 - 44. Preparation for the job is defined as

> "The extent of on-the-job experience required for adequate performance"

and carries 18 possible point values in the range 12-38.

5. TRANSLATION OF BANK B INTO BANK A SCORES

To enable a comparison between the skill input profiles of the two banks, the "skill scores" for all jobs in Bank B were transformed into those of Bank A. (see p.21 of main report). Preliminary examination of the data suggested that, since a percentage-increment method was used to allocate point values used by Bank A, the latter scores when plotted on a logarithmic scale would yield a straight regression line. The regression line is shown in Figure I-1 and was used to obtain the desired transformations.

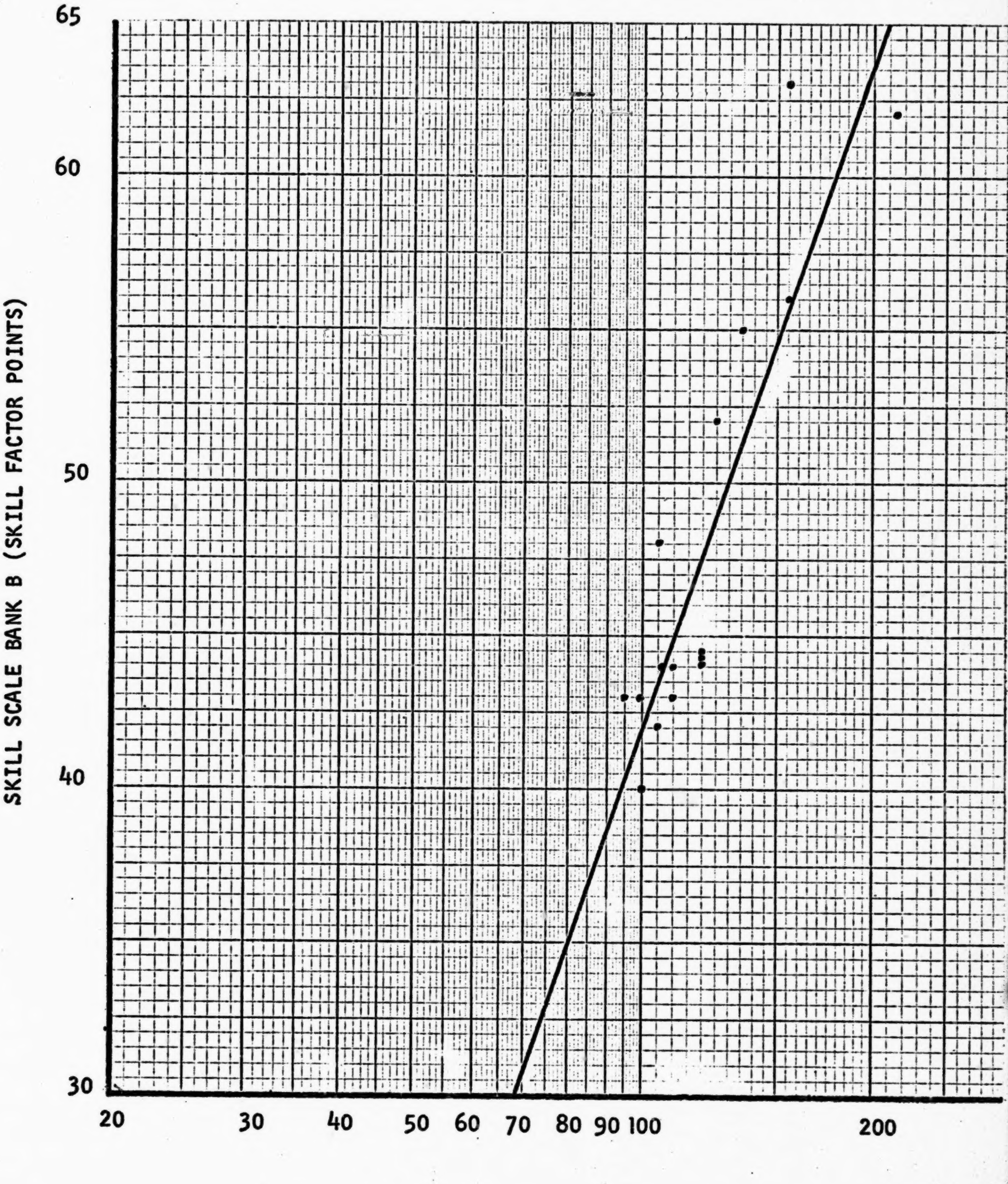
6. RAW DATA USED FOR THE DEVELOPMENT OF SKILL PROFILES

These data are tabulated under the title of each system or sub-system, with the volume of items processed in parentheses. The following notes explain the meaning of each column in the tables:

Job Code:	These codes are internal codes, assigned to each job to facilitate cross referencing. The letter identifies the firm, the attached figure identifies technology and the figure separated by a dash, the job itself.
Job D.O.T. No.:	These six digit numbers are taken from the 1965 edition of the Dictionary of Occupational Titles. The matching of D.O.T. number and job was done by the researchers on the basis of job descriptions and their own knowledge of the jobs.
Job Title:	Official titles assigned to the jobs by the firm.
Skill Level:	Bank A: Total skill factor points derived from the firm's job evaluation scheme. Bank B: Both the skill factor points from this bank's job evaluation scheme (now discontinued) and the transformed values corresponding to Bank A's skill scale are given.
Manhours:	Figures determined from company records and from discussion with management personnel.

FIGURE I - 1: GRAPH FOR CONVERTING BANK B INTO BANK A SKILL POINT RATINGS

Fitted Regression-line: Y = 72x - 102)



SKILL SCALE, BANK A (SKILL FACTOR POINTS ON LOG SCALE)

Volumes: Figures are:

A1 - average of 5 months' recorded volume.

A2 (Attached Branch) - average of 12 months' volume.

A2 (EDP Center) - average of several days' typical volume extracted by manager from records.

B1 - average of volumes for several typical months specified by manager.

B2 (Branch) - average of 8 months' volume.

B2 (Encoding Center) - average of 12 months' volume.

B2 (EDP Center) - average of 12 months' volume.

B2 (Account services) - average of one month's volume.

FIRM A: CHECK PROCESSING AND ACCOUNT POSTING

ND PROCESSING

on-Attached Branch (Volume: 9230 items per week)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Week
A1-1	217.388	Proof Machine Operator	100	40
A1-2	212.368	Paying and Filing Clerk	105	40
A1-3	210.388	Commercial Bookkeeper	105	40
A1-4	212.368	Commercial and Savings Teller-A	119	160

MPUTERIZED PROCESSING

.D.P. Attached Branch (Volume: 60,000 items per week)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Week
A2-1	249.388	Messenger	88	40
A2-2	209.388	Statements Cycling Clerk	92	40
A2-4	212.368	Paying and Filing Clerk-B	105	40
A2-5	217.388	Proof Machine Operator	105	140
A2-7	210.388	Statement Cycling and Reconcilement Clerk	113	80
A2-10	219.388	Returned Items Clerk	119	40
A2-11	212.368	General Teller	119	325
A2-12	210.388	Bookkeeper (General Ledger)	119	35
A2-15	249.368	New Accounts Teller-A	129	25
A2-16	212.368	Branch Utility Clerk-C	136	25
A2-17	210.388	Audit Clerk C	136	30
A2-19	201.368	Secretary Clerk	148	40
A2-22	212.368*	Branch Utility Clerk-B	156	25

lectronic Data Processing Center (Volume: 1,750,000 items per week)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Week
A2-3	222.587	Preparation and Distribution Clerk	92	50
A2-6	217.388	Proof Machine Operator	113	160
A2-8	213.382	Sorter Operator "A"	119	510
A2-9	213.588	Flexotypist	119	160
A2-13	210.388	Reconciler Clerk "A"	126	540
A2-14	202.388	Secretary	126	40
A2-18	213.382	Sorter Operator "B"	136	160
A2-20	213.382	Printer Operator	156	120
A2-21	210.388	Reconciler Clerk "B"	156	120
A2-23	210.388*	Utility Clerk	164	40
A2-24	213.382	Computer Operator	214	240

* This position requires the performance of duties of other jobs
D.O.T. number of highest skilled job is shown.

FIRM A: CHECK PROCESSING AND ACCOUNT POSTING

(Whole Bank System)

A3 HAND PROCESSING

(Prior to introduction of EDP, Total Volume: 10,412,358 items per week)

Branches

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Week
A3-1	249.388	Messenger	88	40
A3-2	249.388	Messenger	88	280
A3-3	217.388	Proof Machine Operator	100	22,100
A3-4	210.388	Bookkeeper Commercial	105	95,360
A3-5	210.388	Chief Bookkeeper-Commercial "C"	113	2,120
A3-6	210.388	Chief Bookkeeper-Commercial "A"	119	3,680
A3-7	210.388	Bookkeeper-General Ledger	119	1,160
A3-8	212.368	Teller-General	119	186,240
A3-9	210.388	Chief Bookkeeper-Commercial "B"	127	520
A3-10	212.368	Utility Employee	136	4,760
A3-11	210.388	Audit Clerk	136	240
A3-12	201.368	Secretary Clerk	148	1,040
A3-13	212.368	Utility Employee	156	600

A4 COMPUTERIZED PROCESSING

(Whole bank, 1965, Total Volume: 13,355,853 items per week)

EDP Attached Branches

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Week
A4-1	249.388	Messenger	88	187
A4-2	249.388	Messenger	88	120
A4-3	209.388	Statement Cycling Clerk	92	1,630
A4-5	209.388	Statement Cycling and Safe Deposit Clerk	100	40
A4-6	210.388	Bookkeeper-Commercial	105	520
A4-7	219.388	Exception Clerk	105	1,520
A4-8	217.388	Proof Machine Operator-Clerk	105	5,402
A4-9	212.368	Paying and Filing Clerk	105	808
A4-10	212.368	Paying and Filing Clerk "B"	105	480
A4-11	212.368	Savings Verification Clerk "A"	105	320
A4-12	212.368	Savings Verification Clerk "B"	105	240
A4-13	219.388	Non-read Clerk	105	120
A4-14	217.388	Proof Machine Operator	105	46,058
A4-15	219.388	Returned Items Clerk "B"	111	2,334
A4-16	219.388 209.388	Clerk	111	16,598
A4-17	210.388	Statement Cycling and Reconcilement Clerk	113	1,254
A4-19	209.388 210.388	Bookkeeper-Service Ledger	119	3,667
A4-20	212.368	Teller-General	119	162,235
A4-21	210.388	Chief Bookkeeper-Commercial "A"	119	40
A4-22	219.388	Returned Items Clerk "A"	119	2,160
A4-23	217.388 212.368	Proof Machine Operator-Teller	119	1,628
A4-24	210.388	Account Reconcilement Clerk	119	1,200
A4-27	219.388 209.388	Senior Clerk	126	680
A4-30	210.388	Audit Clerk	136	120
A4-31	212.368	Utility Employee	136	14,149
A4-32	217.388 210.388	Head of ERMA Section "A"	136	320
A4-34	201.368	Secretary-Clerk	148	2,040
A4-35	212.368	Utility Employee	156	1,520
A4-36	217.388 210.388	Head of ERMA Section "B"	156	120

CON'T. A4 COMPUTERIZED PROCESSING

(Whole bank, 1965, Total Volume: 13,355,853 items per week)

Electronic Data Processing Center

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Week
A4-4	222.587	Preparation and Distribution Clerk	92	2,088
A4-18	217.388	Proof Machine Operator	113	561
A4-25	213.382	Sorter Operator "A"	119	5,020
A4-26	213.588	Flexotypist	119	898
A4-28	210.388	Reconciler Clerk "A"	126	10,255
A4-29	202.388	Secretary	126	2,321
A4-33	213.382	Sorter Operator "B"	136	1,054
A4-37	213.382	Printer Operator	156	1,040
A4-38	210.388	Reconciler Clerk "B"	156	2,534
A4-39	210.388	Utility Clerk	164	160
A4-40	213.382	Computer Operator Trainee	177	800
A4-41	210.388	Operations Assistant "A"	177	480
A4-42	210.388	Operations Assistant "B"	187	120
A4-43	213.382	Computer Operator	214	3,520
A4-44	213.382	Senior Computer Operator	243	360

FIRM B: CHECK PROCESSING AND ACCOUNT POSTING

B1 HAND PROCESSING

Non-Attached Branch (Volume: 45,000 items per month)

Job Code	Job D.O.T. No.	Job Title	Firm B Skill Level	Translated Skill Level	Manhours Per Month
B1-1	210.388	Commercial Bookkeeper	42	100	336
B1-2	212.368	New Accounts Clerk (Steno-Receptionist)	43	103	84
B1-3	217.388	Proof Machine Operator	43	103	84
B1-4	212.368	Commercial and Savings Teller	44	107	462

B2 COMPUTER PROCESSING

E.D.P. Attached Branch (Volume: 72,290 items per week)

Job Code	Job D.O.T. No.	Job Title	Firm B Skill Level	Translated Skill Level	Manhours Per Week
B2-a1	249.388	Mail Clerk	38	87	30
B2-a2	209.388	Statement Clerk	40	94	40
B2-a3	209.388	Statement Clerk	40	94	40
B2-a4	206.388	Branch Clerk	41	97	10
B2-a5	210.388	Branch Clerk	42	100	20
B2-a6	206.388	Utility Clerk	43	103	40
B2-a7	212.368	Commercial and Savings Teller	44	107	288
B2-a8	212.368	Commercial Teller	46	114	40
B2-a9	212.368	Commercial Teller	46	114	105
B2-a10	212.368	Utility Clerk	47	118	30
B2-a11	219.388	EDP Clerk	49	125	40
B2-a12	219.388	POD Clerk	49	125	40
B2-a13	212.368	Branch Clerk	50	129	40
B2-a14	201.368	Branch Steno Receptionist	56	157	50

Encoding Center (Volume: 2,552,900 items per week)

Job Code	Job D.O.T. No.	Job Title	Firm B Skill Level	Translated Skill Level	Manhours Per Week
B2-b1	222.387	Receiving Clerk	38	87	224
B2-b2	217.388	Proof Machine Operator	42	100	2571
B2-b3	216.488	Charge Out Clerk	45	110	120
B2-b4	222.387	Senior Clerk	46	114	40
B2-b5	210.388	Difference Clerk	50	129	128
B2-b6	{210.388 222.388}	Assistant Section Supervisor (Working)	58	167	240

Electronic Data Processing Center (EDP)(Volume: 51,725,800 items per week)

Job Code	Job D.O.T. No.	Job Title	Firm B Skill Level	Translated Skill Level	Manhours Per Week
Assembling, Record Changes, Reconciling					
B2-c1	222.587	Assembler	37	85	871
B2-c2	216.388	Blotter Clerk	42	100	120
B2-c3	213.885	New Accounts Record Change Clerk	43	103	120
B2-c4	210.388	Reconciler	43	103	971
B2-c5	213.588	Flexowriter	46	114	160
B2-c6	210.388	Senior Reconciler	47	118	568
B2-c7	216.388	Chart Clerk	48	122	240
B2-c8	216.388	Control Clerk	49	125	40
B2-c9	216.388	Reconcilement	50	129	120
B2-c10	{216.388 213.885}	Assistant Supervisor (Working)	52	138	80
B2-c11	216.388	Chart Supervisor (Working)	58	167	40
Sorting and Computer Processing					
B2-d1	213.382	Fine Sort Operator	44	107	620
B2-d2	206.388	Tape Librarian	48	122	100
B2-d3	213.382	Fine Sort Coordinator	52	138	80
B2-d4	213.382	Computer Operator	58	167	770
B2-d5	213.382	Senior Computer Operator	62	190	160
B2-d6	213.138	Supervisor (Working)	64	203	80

Con't. Electronic Data Processing Center (EDP) (Volume: 51,725,800 items per week)

Job Code	Job D.O.T. No.	Job Title	Firm B Skill Level	Translated Skill Level	Manhours Per Week
Corrective Encoding, Analyzing, and Sorting					
B2-e1	207.885 249.388	Messenger	36	83	60
B2-e2	249.388	Messenger	37	85	40
B2-e3	207.885	Recordak and Mail Clerk	38	87	150
B2-e4	207.885	Recordaker	38	87	40
B2-e5	207.885 249.388	Mail and Supply Supervisor	39	91	80
B2-e6	249.388	Receiving Clerk	40	94	40
B2-e7	216.388 217.388	Junior Department Clerk	42	100	211
B2-e8	217.388	Junior Proof Operator	42	100	32
B2-e9	217.388	Senior Proof Machine Operator	45	110	958
B2-e10	216.388 210.388	Bank Advisement Clerk	50	129	40
B2-e11	217.388	Senior Settlement Clerk	52	138	40
B2-e12	217.388	Assistant Supervisor (Working)	53	142	40
B2-e13	216.388	Junior Analysis Clerk	53	142	40
B2-e14	216.388	Senior Department Clerk	54	147	200
B2-e15	217.388	Assistant Supervisor (Working)	56	157	40
B2-e16	216.388	Senior Analysis Clerk	58	167	40
Tracing and Internal Adjustments					
B2-f1	216.388 217.388	Tracer Unit Clerk	44	107	100
B2-f2	216.388	Control Unit Clerk	44	107	160
B2-f3	206.388	Senior Records Clerk	48	122	40
B2-f4	216.388 217.388	Senior Tracer Clerk	49	125	40
B2-f5	216.388	Encoding Unit Clerk	52	138	40
B2-f6	201.368	Department Steno Clerk	52	138	40
B2-f7	216.388	Proof of Deposit Clerk	55	152	240
B2-f8	216.388 217.388	Working Supervisor (Encoding)	62	190	40
B2-f9	216.388	Working Supervisor (Tracing)	63	196	40
B2-f10	216.388	Working Supervisor (Control)	63	196	40
B2-f11	216.388	Proof of Deposit Senior Clerk	63	196	40
Processing of Unpaid Items					
B2-g1	249.388	Messenger	36	83	20
B2-g2	210.388	Reclamation Clerk	43	103	40
B2-g3	210.388	Reclamation Clerk	43	103	40
B2-g4	210.388	Reclamation Clerk	43	103	40
B2-g5	210.388	Reclamation Clerk	47	118	150
B2-g6	210.388	Reclamation Clerk	47	118	40
B2-g7	210.388	Reclamation Clerk	54	147	40
Distribution					
B2-h1	222.587	Distribution Clerk	42	100	400
B2-h2	222.587	Working Supervisor	46	114	40
B2-h3	222.587 216.388	Working Supervisor	46	114	40

Account Services (Volume: 736,800 items per week)

Job Code	Job D.O.T. No.	Job Title	Firm B Skill Level	Translated Skill Level	Manhours Per Week
B2-i1	206.388	Junior Clerk	43	103	1120
B2-i2	206.388	Senior Clerk	44	107	400
B2-i3	206.388	Utility Clerk	48	122	240
B2-i4	206.388 210.388	Working Unit Supervisor	52	138	320

7. LENGTH OF OPERATORS' GENERAL EDUCATION AND ON-THE-JOB EXPERIENCE

The internal job codes and job titles used in Section 6 are retained to facilitate cross referencing.

Estimates of general educational requirements made by researchers.

Estimates of on-the-job experience requirements supplied by firms.

FIRM A: CHECK PROCESSING AND ACCOUNT POSTING

Job Code	Job Title	Estimated Required General Education (Years of High School) 0	1-2	3-4	On-the-job Experience (Weeks) 0-1	1-3	4-13	14-26	27-52	53-
A1 HAND PROCESSING										
	Non-attached Branch (Volume: 9230 items/week)									
A1-1	Proof Machine Operator			X			X			
A1-2	Paying and Filing Clerk			X		X				
A1-3	Commercial Bookkeeper			X			X			
A1-4	Commercial and Savings Teller - A			X			X			
A2 COMPUTERIZED PROCESSING										
	E.D.P. Attached Branch (Volume: 60,000 items/week)									
A2-1	Messenger	X			X					
A2-2	Statements Cycling Clerk			X		X				
A2-4	Paying and Filing Clerk - B			X			X			
A2-5	Proof Machine Operator			X			X			
A2-7	Statement Cycling and Reconcilement Clerk			X			X			
A2-10	Returned Items Clerk			X			X			
A2-11	General Teller			X			X			
A2-12	Bookkeeper (General Ledger)			X				X		
A2-15	New Accounts Teller - A			X			X			
A2-16	Branch Utility Clerk - C			X			X			
A2-17	Audit Clerk - C			X			X			
A2-19	Secretary Clerk			X			X			
A2-22	Branch Utility Clerk - B			X				X		
	Electronic Data Processing Center (Volume: 1,750 items/week)									
A2-3	Preparation and Distribution Clerk	X				X				
A2-6	Proof Machine Operator			X			X			
A2-8	Sorter Operator "A"		X				X			
A2-9	Flexotypist		X				X			
A2-13	Reconciler Clerk "A"			X			X			
A2-14	Secretary			X			X			
A2-18	Sorter Operator "B"			X				X		
A2-20	Printer Operator			X					X	
A2-21	Reconciler Clerk "B"			X					X	
A2-23	Utility Clerk			X					X	
A2-24	Computer Operator			X						X

FIRM B: CHECK PROCESSING AND ACCOUNT POSTING

Job Code	Job Title	Estimated Required General Education (Years of High School)			On-the-job Experience (Weeks)			
		0	1-2	3-4	1-3	4-13	14-26	27-52
B1 HAND-PROCESSING								
Non-Attached Branch (Volume: 45,000 items per month)								
B1-1	Commercial Bookkeeper		X				X	
B1-2	New Accounts Clerk (Steno-Receptionist)			X			X	
B1-3	Proof Machine Operator		X				X	
B1-4	Commercial and Savings Teller			X			X	
B2 COMPUTER PROCESSING								
E.D.P. Attached Branch (Volume: 72,290 items per week)								
B2-a1	Mail Clerk	X			X			
B2-a2	Statement Clerk		X			X		
B2-a3	Statement Clerk		X			X		
B2-a4	Branch Clerk		X			X		
B2-a5	Branch Clerk		X				X	
B2-a6	Utility Clerk		X				X	
B2-a7	Commercial and Savings Teller			X			X	
B2-a8	Commercial Teller			X			X	
B2-a9	Commercial Teller			X			X	
B2-a10	Utility Clerk			X			X	
B2-a11	EDP Clerk			X			X	
B2-a12	POD Clerk			X			X	
B2-a13	Branch Clerk			X				X
B2-a14	Branch Steno Receptionist			X				X
Encoding Center (Volume: 2,552,900 items per week)								
B2-b1	Receiving Clerk	X			X			
B2-b2	Proof Machine Operator		X				X	
B2-b3	Charge Out Clerk		X				X	
B2-b4	Senior Clerk		X				X	
B2-b5	Difference Clerk		X				X	
B2-b6	Assistant Section Supervisor (Working)			X				X
Electronic Data Processing Center (EDP) (Volume: 5,715,800 items per week)								
B2-c1	Assembler	X			X			
B2-c2	Blotter Clerk		X				X	
B2-c3	New Accounts Record Change Clerk		X				X	
B2-c4	Reconciler			X			X	
B2-c5	Flexowriter		X				X	
B2-c6	Senior Reconciler			X			X	
B2-c7	Chart Clerk			X			X	
B2-c8	Control Clerk			X			X	
B2-c9	Reconcilement Supervisor (Working)			X			X	
B2-c10	Assistant Supervisor (Working)			X				X
B2-c11	Chart Supervisor (Working)			X				X
Sorting and Computer Processing								
B2-d1	Fine Sort Operator		X				X	
B2-d2	Tape Librarian			X				X
B2-d3	Fine Sort Coordinator			X				X
B2-d4	Computer Operator			X				X
B2-d5	Senior Computer Operator			X				X
B2-d6	Supervisor (Working)			X				X

Con't. Electronic Data Processing Center (EDP) (Volume: 5,715,800 items per week)

Job Code	Job Title	Estimated Required General Education (Years of High School) 0	1-2	3-4	On-the-job Experience (Weeks) 1-3	4-13	14-26	27-52
	Corrective Encoding, Analyzing, and Sorting							
B2-e1	Messenger	X			X			
B2-e2	Messenger	X			X			
B2-e3	Recordak and Mail Clerk	X			X			
B2-e4	Recordaker	X			X			
B2-e5	Mail and Supply Supervisor		X			X		
B2-e6	Receiving Clerk		X			X		
B2-e7	Junior Department Clerk		X				X	
B2-e8	Junior Proof Operator			X			X	
B2-e9	Senior Proof Machine Operator			X			X	
B2-e10	Bank Advisement Clerk			X				X
B2-e11	Senior Settlement Clerk			X				X
B2-e12	Assistant Supervisor (Working)			X				X
B2-e13	Junior Analysis Clerk			X				X
B2-e14	Senior Department Clerk			X				X
B2-e15	Assistant Supervisor (Working)			X				X
B2-e16	Senior Analysis Clerk			X				X
	Tracing and Internal Adjustments							
B2-f1	Tracer Unit Clerk		X				X	
B2-f2	Control Unit Clerk		X				X	
B2-f3	Senior Records Clerk			X			X	
B2-f4	Senior Tracer Clerk			X			X	
B2-f5	Encoding Unit Clerk			X			X	
B2-f6	Department Steno Clerk			X			X	
B2-f7	Proof of Deposit Clerk			X			X	
B2-f8	Working Supervisor (Encoding)			X				X
B2-f9	Working Supervisor (Tracing)			X				X
B2-f10	Working Supervisor (Control)			X				X
B2-f11	Proof of Deposit Senior Clerk			X				X
	Processing of Unpaid Items							
B2-g1	Messenger	X			X			
B2-g2	Reclamation Clerk			X			X	
B2-g3	Reclamation Clerk			X			X	
B2-g4	Reclamation Clerk			X			X	
B2-g5	Reclamation Clerk			X			X	
B2-g6	Reclamation Clerk			X			X	
B2-g7	Reclamation Clerk			X				X
	Distribution							
B2-h1	Distribution Clerk		X				X	
B2-h2	Working Supervisor			X			X	
B2-h3	Working Supervisor			X			X	
	Account Services (Volume: 736,800 items per week)							
B2-i1	Junior Clerk		X				X	
B2-i2	Senior Clerk		X				X	
B2-i3	Utility Clerk			X			X	
B2-i4	Working Unit Supervisor			X			X	

8. ANALYSIS OF VARIANCE LAYOUT OF DATA AND DETAILED SUMMARY

Key to abbreviations:

D.F. - Degrees of freedom

S.S. - Source of squares

M.S. - Mean squares

V.R. - Variance ratio

SL - Skill levels

T - Technology levels

F - Firms

TABLE I - 1

Manhours per unit product classified by skill level, firm and technology

Skill Level	Technology 1		Technology 2	
	Firm 1 (A1)	Firm 2 (B1)	Firm 1 (A2)	Firm 2 (B2)
Low	0.00	0.00	0.67	0.71
Medium	30.33	21.47	12.92	14.62
High	0.00	0.00	2.39	1.60
Totals	30.33	21.47	15.98	16.93

TABLE I - 2

Analysis of Variance Summary

Source of Variance	D.F.	S.S.	M.S.	V.R.	Significance Level
Between skill levels	2	980.19	490.10	126.3	$P < 0.01$
Between technologies	1	14.92	14.92	5.8	
Between firms	1	5.22	5.22	2.0	
SL x T	2	136.67	68.34	26.3	$P < 0.05$
SL x F	2	7.75	3.88	1.5	
T x F	1	22.83	22.83	8.8	
Residual	2	5.19	2.60		
Total	11	1172.77			

9. JOB DESCRIPTIONS

A1: Non-computorized System

Each job title is preceded by the internal job code. The number at the right margin is the skill factor point rating for the job.

AI-1 - Proof Machine Operator	100

Operates proof machine to prove and sort in-clearings and counter work of branch. Runs and balances large consolidation proof, listing proof machine recapitulation totals, totals from other branch batch sheets representing work not processed through proof machine and amounts of teller's cash to and from the vault as shown on tellers' cash proof sheets. Makes clearings exchange with other local banks and receives payment for clearings delivered. Verifies signatures and account balances with inter-branch savings withdrawals. Calls back sections of commercial book.

AI-2 - Paying and Filing Clerk	105

Pays and files posted debits received from EDP (Electronic Data Processing) Center. Processes items through perforator to indicate date of payment. Examines checks for regularity of date, endorsements and amount. Refers irregular items to officers for further disposition. Verifies maker's signature, answers telephone inquiries, reviews deposits sorted through proof machines to determine accuracy and completeness of coding and makes adjustments and corrections. Receives and processes statements for delivery or mailing to branch customers, processes and delivers statements, operates NCR or IBM proof machine as necessary.

AI-3 - Commercial Bookkeeper	105

Maintains permanent records of commercial accounts by machine posting debits and credits to individual ledgers and statements. Receives checks and deposits to be posted to individual accounts. Sorts items into alphabetical order. Segregates and disposes of mis-sorts according to instructions. Picks up balance on ledger sheet and posts debits and credits by machine. When finished postings, strikes totals of debits and credits on carbon copy of bookkeepers register. Compares and balances totals of own register with distribution register control or consolidated totals with those of other bookkeepers and balances with branch consolidation blotter. Posts bookkeepers summary of registers and controls. Cancels posted checks in perforating machine. Posts service charges monthly.

AI-4 - Commercial and Savings Teller A	119

Accepts commercial and savings deposits. Cashes checks and pays savings withdrawals. Sorts own deposit and withdrawal tickets, and cash paid and deposited items, runs and proves teller's batch. Acts as vault teller. Sells traveler's checks, domestic exchange, and U.S. Savings Bonds, cashes U.S. Savings Bonds and domestic bond coupons. Accepts withholding tax payments. Accepts commercial and loan payments and installment collection payments. Makes up cash payrolls. Opens new accounts, admits customers to safe deposit vault, rents boxes, and receives rentals. Calls back commercial books, runs consolidation blotter, files signature cards and ledger cards, receives and processes in-mail deposits, recordaks pay items. Runs and proves teller's batches. Runs the in-mail, in-clearing, out-clearing and/or transit. Runs, posts and proves various registers and ledger cards.Computes service charges. Puts up commercial statements. Runs and proves savings interest. Writes up return item ledgers and entry letters. Audits cashier check stubs. Computes loan accruals. May post commercial book or run proof machines. Compiles data for various reports.

A2: Computorized System including a Branch Office and Electronic Data Processing Center

Each job title is preceded by the internal job code. The number at the right margin is the skill factor point rating for the job.

A2-1 - EDP Attached Branch - Messenger 88

Maintains, issues and controls branch supplies. Delivers mail, clearing, supplies and various other items for the branch. Acts as safe deposit custodian.

A2-2 - EDP Attached Branch - Statements Cycling Clerk 92

Prepares cycle statements for delivery of mailing to branch customers. Delivers statements to customers, answers telephone inquiries regarding account status, placing of holds or stop payments or customer complaints. Pays and files checks processed through EDP. Operates NCR or IBM proof machine as necessary. Prepares record changes and various reports for the EDP Center. Receives and prepares checkbook and deposit slip orders. Photographs deposit slips and all outgoing clearings.

A2-3 - EDP Center - Preparation and Distribution Clerk

Receives, records, sorts and prepares incoming material for computer processing. Processes and sorts imprinted forms and other items for return to branches. Receives checks and stores incoming supplies. Assists with the preparation of magnetic tape for shipment.

A2-4 - EDP Attached Branch - Paying and Filing Clerk B 105

Pays and files posted debits and credits received from EDP Center. Receives and processes commercial statements for mailing or delivery to customers. Answers telephone inquiries regarding account status, placing of holds, stop payments or customer complaints. Assists customers in reconcilement of statements. Receives and prepares check and deposit slip orders.

A2-5 - EDP Attached Branch - Proof Machine Operator 105

Operates proof machine to prove and sort in-clearings and counter work of branch and prepare or complete branch debits and credits for processing through EDP Center. Runs and balances branch consolidation proof, listing proof machine recapitulation totals, totals from other branch batch sheets for work not processed through machine and amounts of tellers' cash to and from vaults. Makes clearing with other local banks. Prepares debit and credit packages for transmittal to EDP Center. Verifies signatures and account balances of inter-branch savings withdrawals received in clearings. Photographs deposit slips and all out-going clearings. Pays and files checks processed through EDP Center. Answers telephone inquiries regarding account status, placing holds or stop payments or customer complaints. Delivers statements to customers, prepares record changes and various reports for EDP Center. Sorts, seals and stamps out-going mail.

A2-6 - EDP Center - Proof Machine Operator 113

Operates proof machine to list balanced batch totals, prove, reconcile and sort batches and prepare or complete branch or section debits and credits for processing through section. Prepares consolidated recap. Balances to merge totals compiled by computer. Assists in first or second computer entry run.

A2-7 - EDP Attached Branch - Statement Cycling and Reconcilement Clerk 113

Prepares cycled statements for delivery or mailing to branch customers. Delivers statements to customers. Reconciles discrepancies in customer and branch account records. Answers telephone inquiries regarding such matters as account status, placing of holds or stop payments or customer complaints. Pays and files checks processed through EDP Center. Operates NCR or IBM proof machine as necessary. Sorts, seals and stamps outgoing mail. Prepares records and various reports for EDP Center. Receives and prepares checkbook and deposit slip orders. Photographs deposit slips and all outgoing clearings.

A2-8 - EDP Center - Sorter Operator A 119

Operates sorter off-line (that is, not under computer control) to read and sort magnetically coded documents, effecting a break-out by individual branch codes and then sorts sequentially by individual account numbers. The operation takes place after the entry run and when the center work is in balance.

A2-9 - EDP Center - Flexotypist 119

Operates flexowriter to produce punched paper tape of record information and changes in binary code for computer input. Operates flexowriter to produce punched paper tape of material used in deletion run. Assists in checking information with supervisor. Reviews various branch record changes prior to typing and locates obvious errors. Periodically flexowrites various phases of the computer program. Assists with various phases of reconciling or mail processing.

A2-10 - EDP Attached Branch - Returned Items Clerk 119

Receives and processes branch checks and other entries rejected by EDP Center for bookkeeping reasons. Receives and processes incoming returned items for banks and other branches. Answers telephone inquiries regarding such matters as account status, placing of holds or stop payments or customer complaints. Pays and files checks processed through EDP Center. Delivers statements to customers. Operates NCR or IBM proof machine.

A2-11 - EDP Attached Branch - General Teller 119

Accepts deposits, cashes checks, pays savings withdrawals and counts and balances cash. Sells traveler's checks, domestic exchange, and U.S. Savings Bonds. Cashes U.S. Savings Bonds and domestic bond coupons, and accepts withholding tax payments. Accepts commercial and time-plan loan payments and installment collection payments. Makes up cash payrolls. Opens new accounts, admits customers to safe deposit vault, rents boxes and receives rentals. Certifies checks. Calls back commercial book. Runs consolidation blotter, files signature cards and ledger cards, receives and processes in-mail deposits, recordaks paid items. Runs and proves teller's batches. Runs in-mail, in-clearing, out-clearing or transit items. Runs, posts, and proves various registers and ledger cards. Computes service charges. Puts up commercial statements. Runs and proves savings interest and prepares return item letters and entry letters. Audits cashier check stubs. Computes loan accruals and compiles data for various reports. May perform one or more of the following duties: act as Vault Teller, process merchant's deposits received over counter, receive incoming collection items and verify all essentials of instrument, and post general ledger.

A2-12 - EDP Attached Branch - Bookkeeper, General Ledger 119

Posts and proves the general ledger. Compiles data from general ledger accounts and makes up a number of reports such as Branch Financial Statements, Recapitulation of Debit and Loan Segregation, Branch Profit and Loss Statement, etc. Assists in locating information requested on branch clearing tracers. Assists other departments in balancing their daily work.

A2-13 - EDP Center - Reconciler Clerk A

Verifies that batch total after entry run is in balance to total charged by branch. If in balance, forwards items for further processing, i.e., recording and entry run. Cross checks out-of-balance batches to locate and adjust errors and to resolve differences between section and branch totals. Prepares batches of items for entry run. Prepares adding machine listing tapes after entry run of rejected items. Assists with the sorting of outgoing items. May operate proof machine to re-sort non-read items for return to branches. Assists Proof Machine Operators with processing work.

A2-14 - EDP Center - Secretary 126

Takes and transcribes dictation from EDP Center manager and his assistants. Maintains clerical control of personnel and operation records, and performs various duties pertinent to the administration of the EDP Center manager's functions.

A2-15 - EDP Attached Branch - New Accounts Teller A 129

Opens new checking, savings and special purpose accounts for individuals, corporations, and organizations. Prepares and mails form to reference bank. Orders checks, deposit tickets, and endorsement stamps. Bills customers' or charges account when necessary. Reconciles branch records to monthly bill from printer and prepares entries to proper accounts. Answers customers inquiries. Accepts commercial and savings deposits. Pays savings withdrawals and cashes checks. Receives requests for signature changes on commercial accounts. Receives requests for and delivers statements to customers. Transfers cash received to teller and obtains receipt or balances daily cash and transfers excess to Vault Teller.

A2-16 - EDP Attached Branch - Branch Utility Clerk C 136

Relieves and performs in all or several of the positions or comparable positions as assigned; Commercial and Savings Teller, General Ledger Bookkeeper, Vault Teller, Note Teller, Collection and Exchange Teller. May relieve Operations Assistant or assist Operations Officer in certification of accounts and preparation of reports. Lists and balances to controls accounts being certified. Traces differences and searches for errors. Compiles reports, instructs new employees and answers questions. Trains new and re-assigned employees and discusses employee's progress with supervisor. May relieve in other capacities.

A2-17 - EDP Attached Branch - Audit Clerk C 136

Maintains records; has custody of reserve supply of numbered forms and supplies them to departments upon request. Maintains control of vault supply of traveler's checks. Maintains furniture and equipment inventory control. Issues cashier's checks in payment of bills incurred by branch. Searches branch records for information requested by authorized government agents. Assists in listing and balancing proofs, counts teller's cash and vault cash. Discusses with customers referred to him errors and adjustments on their accounts, service complaints and charges, attachments, stop payments, etc. Trains new employees. Approves checks over teller's cashing limit. Relieves as Note Teller, New Accounts Teller, General Ledger Bookkeeper, Reconcilement Clerk, Supply Clerk, etc. Posts cash control records and compiles cash control reports. Types revised lists of dormant accounts and posts dormant charges. Reviews inactive commercial ledgers. Calculates or checks calculations of overtime pay due staff. Semi-annually calculates inter-branch expense and note charges. Annually searches for records for bank inspectors and answers queries.

A2-18 - EDP Center - Sorter Operator B 136

Controls the activities of three to seven Sorter Operators. Operates sorter during both on-line and off-line operations. Trains and instructs new operators in procedure and performance of duties. Maintains record of machine utilization time. Wires boards for control of sorting operation and performs various related operational and machine operating duties.

A2-19 - EDP Attached Branch - Secretary Clerk 148

Takes and transcribes dictation from Operations Officer and assistants regarding the servicing of accounts, branch operating procedures, requests for special services, reports to bank headquarters, and employment and personnel matters. Performs various duties which relieve Operations Officer of details concerning personnel matters and routine operations. Files correspondence, circulars, etc. Maintains file of bills from which is calculated money due back from customers for such service as telephone tie lines, night depository, and armored car service. Puts up monthly statement.

A2-20 - EDP Center - Printer Operator 156

Operates high speed printer to prepare statements, registers, and various other computer produced reports. Maintains record of machine utilization time. Operates sorter or performs the duties of Reconciler Clerk in assisting with the processing of work. Operates de-leaver machine and time machine to secure bundles for dispatch.

A2-21 - EDP Center - Reconciler Clerk B 156

Checks and balances the more difficult out-of-balance batches. Assists in the control of employees engaged in reconciling and proofing of batches and assists in maintaining section control. Sorts, lists and balances items that sorter could not read. Prepares settlement branch clearing letters.

Prepares recap of items processed. Assists Proof Machine Operator in correction of errors.

A2-22 - EDP Attached Branch - Branch Utility Clerk B 156

Relieves for Note Teller, Collection and Exchange Teller, Operations Assistant, Note Clerk or Head of Note Department. Assists Operations Officer in certifications of accounts and preparation of reports. Lists and balances to controls accounts being certified. Traces differences and searches for errors. Compiles reports and instructs new employees. May also relieve for Delinquent Loan Follower, New Accounts Teller, Facility Head, Escrow Processor, General Ledger Bookkeeper, Vault Teller and Commercial and Savings Teller.

A2-23 - EDP Center - Utility Clerk 164

Relieves for Operations Assistant, Printer Operator, Reconciler Clerk B, or Sorter Operator B. Trains new and reassigned employees. Also relieves for Reconciler Clerk A, Sorter Operator A, Flexotypist, Proof Machine Operator or Preparation and Distribution Clerk.

A2-24 - EDP Center - Computer Operator 214

Operates computer and associated equipment. May assist supervisor in controlling activities of Peripheral Equipment Operators. Assists supervisor in handling problems and duties confronting other employees on assigned shift. Suggests methods of programming changes to supervisor. Directs employees assigned to him for training. Prepares files and rotates magnetic tapes in accordance with standard schedule. During pressure periods relieves for Assistant Manager, Branch Liaison Officer, Operations Assistant, Printer Operator, Sorter Operator or Reconciler, or Flexotypist.

The Bank B personnel system is not by and large conceived in terms of job titles. In many cases, therefore, descriptive job titles have been devised by the researchers themselves in such a way that they adequately characterize the main job content.

The first set of job descriptions refers to a branch which is not attached to the EDP Center and in the present study represents Technological Level 1.

B1; Non-computorized System

Each job title is preceded by the internal job code. The bracketed number at the right margin is the skill factor point rating on the Bank B scale; the following number is the corresponding skill factor point rating on the Bank A scale.

B1-1 - Commercial Bookkeeper	(42)	100

Sorts and posts commercial books. Receives bookkeeping phone calls. Prepares return items. Transfers and prepares statements. Handles overdraft records and files checks.

B1-2 - New Accounts Clerk	(43)	103

Answers telephone. Opens new accounts. Files correspondence. Takes dictation and types letters. Types new account report. Files signature cards. Pays bank bills. Does miscellaneous typing assignments. Phones, verifying checks and types statements for new accounts.

B1-3 - Proof Machine Operator (also partly acting as General Ledger Teller)	(43)	103

Operates proof machine, proving and sorting items. Pays and receives commercial and savings deposits. May maintain reserve cash. Recaps teller batches and may balance general ledger tickets.

B1-4 - Commercial and Savings Teller	(44)	107

Pays and receives commercial and savings deposits. Has check cashing authority within established limits. Balances cash at close of business. Performs related clerical duties. May handle incoming mail deposits.

B2: Computorized System including a Branch Office, Electronic Data Processing Center, etc.

Each job title is preceded by the internal job code. The number at the right margin is the skill factor point rating for the job.

BRANCH OFFICE ATTACHED TO THE ELECTRONIC DATA PROCESSING CENTER

B2-a1 - Mail Clerk (38) 87

Performs minor clerical functions such as sorting, sealing, and stamping the mail. May deliver mail or run special errands.

B2-a2 - Statement Clerk (40) 94

Does daily report on open and closed accounts. Proves closed signature cards. Determines reason for closing account. Files cards. Makes up statements. Works on statement window. Answers questions in person and on phone. Gives credit rating on commercial accounts. Closes accounts, handles stop payment orders and changes of address on commercial accounts.

B2-a3 - Statement Clerk (40) 94

Orders printed checks. Makes up statements. Works on statement window. Answers questions in person and on phone. Gives credit ratings on commercial accounts. Handles window corrections. Closes accounts.

B2-a4 - Branch Clerk (41) 97

Handles bank-by-mail. Mails passbooks and inserts. Checks changes of address.Makes up new passbooks for new customers and for filled passbooks. Files commercial checks, statements, letters and miscellaneous items. Operates addressograph. From obituary notices in the daily press types notices to departments concerned with the death of a customer. Checks the same departments for head office tracers and bankruptcy lists.

B2-a5 - Branch Clerk (42) 100

Answers all incoming savings calls concerning credit ratings, balance verifications, and close outs. Handles savings automatic transfers. Runs proof control of savings certificates. Performs other clerical duties, notably typing as required.

B2-a6 - Utility Clerk (43) 103

Opens and sorts mail by endorsement. Photographs and lists work being returned to other banks. Receives and sorts returns from other banks. Credits incoming returns from other banks. Runs work to computer on teller's pay ticket. Photographs and balances morning work. Relieves in statement department, at window and on phones.

B2-a7 - Commercial and Savings Teller (44) 107

Pays and receives commercial and savings deposits. Balances cash at close of business. Performs related clerical duties. May handle incoming mail deposits.

B2-a8 - Commercial Teller (46) 114

Pays and receives commercial items. Runs department blotter. Handles in-mail deposits. Pays signatures on "us" checks. Prepares service charges. Sorts "us" checks. Answers phone calls. Maintains commerical signature card file. Trains others.

B2-a9 - Commercial Teller (46) 114

Pays and receives commercial deposits. Has check cashing authority within established limits. Balances cash at close of business. Performs related clerical duties. May handle incoming mail deposits.

B2-a10 - Utility Clerk (47) 118

Acts as Commercial Paying and Receiving Teller, as Savings Paying and Receiving Teller and as Teller Trainer as required. Relieves Collection and Exchange Teller and acts as General Bookkeeper as required.

B2-a11 - EDP Clerk (49) 125

Is responsible for reconciling work received from computer center, Prepares outgoing reclamations. Handles mis-sorts. Prepares overdraft and go-back reports, charges and notices. Reviews new accounts and record change list for accuracy of information. Has contact with customers regarding commercial account problems.

B2-a12 - POD Clerk (49) 125

Same as for B2-a11 - but in addition photographs items leaving branch.

B2-a13 - Branch Clerk (50) 129

Assists Operations Supervisor. Handles customer problems and complaints. Locates differences. Acts in relief capacity in books, teller work, proof operator work, etc.

B2-a14 - Branch Steno Receptionist (56) 157

Waits on customers. Opens new accounts. Types daily overdraft report, and daily report of new accounts. Types all new commerical and savings accounts. Types report of overdrafts over $1,000.00 daily. Makes up monthly overdraft report to head office. Sends out monthly letters requesting permanent signature cards. Sends out yearly memoranda to other offices requesting any changes in accommodation cards. Types forms for returning checks for endorsement of payee. Takes dictation and types letters for three platform officers.

ENCODING CENTER

B2-b1 - Receiving Clerk (38) 87

Checks in proof-of-deposit work received from branches. Records time of arrival and weighs in work received. Sorts out support documents at conclusion of operation. Delivers encoded work to assembling area. Checks condition of work received.

B2-b2 - Proof Machine Operator (42) 100

Operates proof machine, proving and sorting in-mail, counter work, and in-clearings from branch. Prepares or completes branch debits and credits for processing through computer center. Encodes dollar amount and other information. Totals out machine at end of day.

B2-b3 - Charge-Out Clerk (45) 110

Picks up processed work from Proof-of-Deposit Operators at regular intervals. Inspects work for quality of encoding. Charges work to proof-of-deposit computer. Balances section at end of day to operator recaps. May assist operators in balancing. May assist supervisors in work distribution.

B2-b4 - Senior Clerk (46) 114

Checks that all work arrives on time and is weighed for activity purposes. Spot checks for proper breakdown of incoming work. Checks incoming work for endorsement verification and orderliness of work. Assists in sorting support documents. Is familiar with special handling of certain large deposits. Prepares special branch settlement letters for processing. Prepares daily report of all late deliveries and other exceptions.

B2-b5 - Difference Clerk (50) 129

Writes up differences located in the proof-of-deposit unit and coding operation. May assist operator in locating and correcting out-of-balance conditions. Telephones branches to advise of teller differences or large deposit differences.

B2-b6 - Assistant Section Supervisor (Working) (58) 167

Distributes work to operators and assists operators in balancing problems. Coordinates flow of work from section to recapping machines. Assists in final department balancing.

EDP CENTER: ASSEMBLING, RECORD CHANGES AND RECONCILING

B2-c1 - Assembler (37) 85

May in-prove bundles of checks or deposits on adding machine and balance to branch settlement letter. Assembles items for computer processing. Places bundles in trays and identifies type of work and block number. Prepares outgoing cash letters.

B2-c2 - Blotter Clerk (42) 100

Balances each Reconciler's correction sheet. Sorts debit and credit entries on IBM machine. Charges debit and credit rejects to transit department's manual operations. Balances in-proof blotter for the department. Establishes initial dollar controls for chart. Checks different entries for offsets. Sorts IBM cards for proof-of-deposit editing.

B2-c3 - New Accounts Record Change Clerk (43) 103

Processes daily all new accounts, record changes, and reversals for demand-deposit accounts. Processes all stop payments and stop payment releases. Processes all commercial bookkeeping reversals (this involves key punching and reconciling out-of-balance conditions).

B2-c4 - Reconciler (43) 103

Checks out-of-balance blocks by batch. When cause of discrepancy is located, prepares an adjusting entry to correct out-of-balance condition. May check computer process work for missing items. This involves locating and checking items preceding and following missing item. Prepares reconciler correction sheet with necessary adjusting entries and other totals.

B2-c5 - Flexowriter (46) 114

Operates machines used in up-dating savings information from branches. Operates flexowriter in typing new accounts and name and address changes for savings accounts. Operates 10-key adding machine with high speed tape punching mechanism.

B2-c6 - Senior Reconciler (47) 118

Same as for B2-c4.

B2-c7 - Chart Clerk (48) 122

Balances the proof-of-deposit computer operation by preparing adding machine listings of sort pass rejects from computer pockets, accumulating pocket totals from block control sheets, balancing transit pockets and locating pocket differences.

B2-c8 - Control Clerk (49) 125

Balances unprocessed item journal of special accounts. Assists in locating computer analysis discrepancies. Balances and controls card data capture reconcilement of rejected debits and credits. Checks stray items on activity list journal to minimize differences. May assist in proof-of-deposit reconciling. Answers inquiries from branches with respect to unprocessed general ledger entries or out-of-balance conditions. Assists Savings Supervisor in answering phone inquiries. Handles general clerical tasks related to electronic data processing control bookkeeping.

B2-c9 - Reconcilement Supervisor (Working) (50) 129

Assists Reconcilers in balancing difficult out-of-balance blocks. May himself reconcile blocks.

B2-c10 - Assistant Supervisor (Working) (52) 138

Assists in the ultimate balancing of approximately 900,000 items daily. Ensures even flow of work to the computer operation. Ensures dispatch on time of various transit cash letter sendings. Assists in cross-training of personnel.

B2-c11 - Chart Supervisor (Working) (58) 167

Assists Chart Clerks in the ultimate balancing of the proof-of-deposit computer operation. May operate computer to prepare final report card.

EDP CENTER: SORTING AND COMPUTER PROCESSING OPERATIONS

B2-d1 - Fine Sort Operator (44) 107

Receives documents from various data capture operations and operates document sorter to break out encoded debits and credits by branch code. Subsequently fine sorts documents into individual account number sequences. Refers discrepancies to supervisor.

B2-d2 - Tape Librarian (48) 122

Classifies, catalogs, and labels tape reels according to data content and routine type. Prepares reference records and stores reels according to classification. Issues tapes for daily application. Up-dates storage records. Checks for damaged reels and erases and releases obsolete tapes for reuse.

B2-d3 - Fine Sort Coordinator (52) 138

Prepares deadline reports. Checks and lists all outgoing sorted work. Checks for proper sorting and editing for each group of debits and credits before release to data control for distribution to branches. Staples all mis-sorted items. Logs all mistakes made by operators and discusses sorting errors with them. Processes all data capture items, debits and credits as soon as possible and delivers to data control. At end of work day checks all machines for stray documents. Acts as back-up for Fine Sort Supervisor.

B2-d4 - Computer Operator (58) 167

Processes work from various divisions within data processing department on the computers. Maintains machine utilization log and production reports. From program instruction sheet determines equipment set up and operating instructions. Prepares the computer output, printed lists and reports for routing to clerical operations. Labels tapes for library. Trains new operators.

B2-d5 - Senior Computer Operator (62) 190

Runs a variety of programs on the computer system. Interprets and makes correct responses to messages presented by computer. Properly responds to system or tape failures and takes corrective action. Interprets and complies with individual programers' written instructions. Sees that each reel of tape is correctly labelled, logged and used at the right time. Sees that each job is completed or communicates with operators on the next shift in the event that the job overlaps from one shift to another.

B2-d6 - Supervisor (Working) (64) 203

May run any of a variety of computer applications whenever necessary. Assists shift supervisor in scheduling the most efficient use of time and equipment for running a wide variety of jobs so that output deadlines are met. Trains new operators. Analyzes input, program or machine trouble. Makes decisions about how the situation is to be corrected and directs operators in carrying out his decisions. Supervises the flow of input and output. Stands in for shift supervisor.

EDP CENTER: CORRECTIVE,AND ENCODING, ANALYZING AND SORTING OPERATIONS

B2-e1 - Messenger (36) 83

Operates recordak machine to photograph outgoing cash letters and performs general messenger duties as assigned.

B2-e2 - Messenger (37) 85

Receives mail from mail room and from various stations in the department and distributes as required.

B2-e3 - Recordak and Mail Clerk (38) 87

Recordaks outgoing transit cash letters. Mails outgoing transit cash letters. Prepares certain types of items for charge to computer and balances on proof machine. Processes special deposits. Recordaks balances and endorses checks. Assists in balancing and in recapping of manual transit sets.

B2-e4 - Recordaker (38) 87

Sets up recordak machine and microfilms day crew items.

B2-e5 - Mail and supply Supervisor (Working) (39) 91

Works with crew of three Recordak Mail Clerks. Assists in recordaking outgoing cash letters, and maintains supply of cash letter forms for correspondent sendings. Mails outgoing correspondent cash letters.

B2-e6 - Receiving Clerk (40) 94

Periodically picks up, delivers and distributes incoming mail from airport, post office and other banks in area. Opens mails, date stamps and distributes as necessary. Sets up bags by office for dispatch of return items and rejects.

B2-e7 - Junior Department Clerk (42) 100

May operate proof machine in processing of reject credits. Prepares branch settlement letters for credits returned or charge to key punch for credits processed. Writes differences for Proof Operator. Charges out work to proof-of-deposit computer. May assist operator in balancing. May make manual analysis of cash letters received from correspondent banks.

B2-e8 - Junior Proof Operator (42) 100

Sorts checks and/or deposits to various destinations by reference to sorting guide. Prepares adjustments for out-of-balance conditions. Balances machine and charges sorted work to various destinations.

B2-e9 - Senior Proof Machine Operator (45) 110

Operates proof machine, proving and sorting in-mail, counter work and in-clearing of branch. Prepares or completes branch debits and credits for processing through computer center. Encodes dollar amount and other information. Totals out machine at end of day.

B2-e10 - Bank Advisement Clerk (50) 129

Assists in distribution of work to operators and assists operators in balancing. Prepares differences for proof Operators. Balances encoded clearing and correspondent bank work. May deal with local clearing banks on clearing errors. May operate proof machine in processing of reject credits. Prepares branch settlement letters for credits returned or charge to key punch for credits processed. May prepare final clearing house recap from all three shifts.

B2-e11 - Senior Settlement Clerk (52) 138

Charges out cash letters from previous days proofs. Controls outstanding items accounts and collections from out of town accounts and of two to three day federal accounts. Audits work of Transit Set Operators.

B2-e12 - Assistant Supervisor (Working) (53) 142

Expedites processing of correspondent cash letters, branch settlement letters, and large volume of rejected computer items. Assists in overall supervision of approximately 30 Proof Operators and 10 Clerks.

B2-e13 - Junior Analysis Clerk (53) 142

Records and calculates activity and credit cycles.reversals for incorrect posting. May assist in preparation of special detailed analyses of sending back correspondence. Assists in preparation of correspondent bank information forms. Assists in tracing and daily balancing of computer-generated analysis report of demand-deposit accounts.

B2-e14 - Senior Department Clerk (54) 147

Assists operators in balancing and assists in training of new operators. Writes up differences for Proof Machine Operators. Checks operators' work for quality of encoding and proper sorting of items. Prepares work for charge-out to other sections. Assists supervisor in final balancing of department.

B2-e15 - Assistant Supervisor (Working) (56) 157

Assists supervisor in overall supervision of personnel in section. Is responsible for expediting processing of correspondent cash letters, branch settlement letters, incoming clearing and rejected computer items. Has substantial contact with other departments, branches, and correspondent banks.

B2-e16 - Senior Analysis Clerk (58) 167

Reviews calculations of items deposited, credit cycles, and float on incoming correspondent cash letters. Originates reversal entries for incorrect postings. Performs special detailed analyses of types of sendings by correspondent banks. Prepares bank account analysis statement summarizing earnings or loss on correspondent bank accounts. Prepares correspondent bank information forms. Corrects daily computer-generated analysis report for demand-deposit accounts and dispatches to central analysis department. Traces invalid computer-generated analysis reports on request of central analysis department.

EDP CENTER: TRACING AND INTERNAL ADJUSTMENT OPERATIONS

B2-f1 - Tracer Unit Clerk (44) 107

Traces items assigned by unit supervisor. Determines if a tracer covers an existing difference. If no difference present, traces item to original source. Obtains photostat or description of item.

B2-f2 - Control Unit Clerk (44) 107

Identifies new adjustments as to date and source. Assists in running and balancing the blotter of entries cleared during the day.

B2-f3 - Senior Records Clerk (48) 122

Is responsible for all records being properly boxed, labelled, and stored. Is responsible for inventory and filing of recordak film. Prepares records for storage and destruction.

B2-f4 - Senior Tracer Clerk (49) 125

Traces items assigned by unit supervisor. Determines if a tracer covers an existing difference. If no difference present, traces item to original source. Obtains photostat or description of item.

B2-f5 - Encoding Unit Clerk (52) 138

Carries out complicated procedures to trace encoding differences to source and takes corrective action to clear differences. Advises supervisor of any procedure not being followed by Reconcilers and other personnel.

B2-f6 - Department Steno Clerk (52) 138

Takes dictation and types all correspondence for section manager and supervisor. Types all adjusting entries to correspondent banks. Prepares verification requests to branches on stray deposits. Maintains correspondence file and follow-up. Does general departmental filing and carries out miscellaneous clerical duties as assigned.

B2-f7 - Proof of Deposit Clerk (55) 152

Carries out complicated procedures to trace computer or manual differences to source and takes corrective action to clear differences. Advises supervisors of any procedures not being followed by Reconcilers and other personnel.

B2-f8 - Working Supervisor Encoding (62) 190

Advises Adjustment Section Manager of errors by other department personnel in preparing adjustment entries. Oversees maintenance of records of one unit of the Encoding Center. Handles extremely heavy volume of telephone inquiries from branches. Reviews all differences received from control unit personnel to verify that information is complete and assigns differences for checking.

B2-f9 - Working Supervisor Tracing (63) 196

Traces items of a confidential nature as received from auditing department. Determines priority of tracer requests. Advises Department Head of backlog and problems in section. Is responsible for training and crosstraining personnel in unit.

B2-f10 - Working Supervisor Control (63) 196

Is responsible for the daily balancing of the difference account to the general ledger.

B2-f11 - Proof of Deposit Senior Clerk (63) 196

Traces computer or manual differences to source and takes corrective action to clear differences; this may involve tracing an item through several departments. Advises supervisors of any procedures not being followed by Reconcilers and other personnel.

EDP CENTER : PROCESSING OF UNPAID ITEMS OPERATIONS

B2-g1 - Messenger (36) 83

Picks up checks deposited at one branch office and transports them to operations center. Handles other special message assignments. Assists in filing.

B2-g2 - Reclamation Clerk (43) 103

Traces requests from auditing department. Traces returned checks that could not be processed due to failure of banks to endorse and determines where items are received so that charge can be made to correct endorser. Assists department supervisor in checking various differences. Assists other department desks in the event of absence or heavy volume.

B2-g3 - Reclamation Clerk (43) 103

Opens incoming return letters, writes reclamation checks, runs proof machine, traces return items that could not be identified and locates endorser.

B2-g4 - Reclamation Clerk (43) 103

Receives checks from reclamation proof machines, sorts items by hand, and determines endorser. Checks mis-sorts from country reclamations. Notifies endorser on delayed items over $200.00.

B2-g5 - Reclamation Clerk (47) 118

Processes return items from country offices and correspondent banks on proof machine; and prepares return item letters.

B2-g6 - Reclamation Clerk (47) 118

Processes return items from city branches and clearing banks on proof machine and sorts checks to endorsing banks. Prepares return item letters.

B2-g7 - Reclamation Clerk (54) 147

Receives incoming telephone calls and telegrams regarding notification of unpaid items from branches and correspondents. Notifies endorser by wire or phone call of unpaid items and delayed returns..

EDP CENTER: DISTRIBUTION OPERATIONS

B2-h1 - Distribution Clerk (42) 100

Processes and distributes computer-generated work to branches. Prepares envelopes and bags for distribution. Hand-sorts rejected debits and credits from computer fine sort. Bursts, decolates and assembles machine produced reports. Verifies fine-sorted checks and deposits. Distributes work to bins and bags. Verifies paper work at end of shift.

B2-h2 - Working Supervisor (46) 114

Oversees and assists Receiving Clerks and Burster Operators. Ensures fast distribution of incoming work to various departments.

B2-h3 - Working Supervisor (46) 114

Supervises and assists in dispatch of work back to branches. Coordinates computer printer output with distribution of general ledger bookkeeping and savings reports. Returns errors in fine sort work or reports for reprocessing.

Assists Bookkeeping Control Clerk in balancing, if necessary. Makes up nightly report of all exceptions for distribution to key day offices and personnel.

ACCOUNT SERVICES

B2-i1 - Junior Clerk	(43) 103

Inter-sorts unsorted checks, checks overdraft limit code appearing on daily overdraft register and reviews stop payment suspect list. Files checks in automated check file unit by account number. Removes checks from file and prepares customer statements for mailing. Answers routine telephone inquiries from branches.

B2-i2 - Senior Clerk	(44) 107

Same as for B2-i1.

B2-i3 - Utility Clerk	(48) 122

Assists with peak volumes and relieves for Account Services Clerk. Assists group supervisor and assumes his responsibilities in case of absence.

B2-i4 - Working Unit Supervisor	(52) 138

Reviews overdrawn accounts noted on daily overdraft register and returns checks unpaid. Reviews unprocessed items and prepares substitute document. Prepares offsetting entries for total unprocessed commercial bookkeeping, debits and credits, for each office. Lists general ledger items. Records returned items and register of debit posting reversals for each branch.

APPENDIX II

STEEL

Box and Continuous Annealing

APPENDIX II

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1. OUTLINE OF TECHNOLOGIES

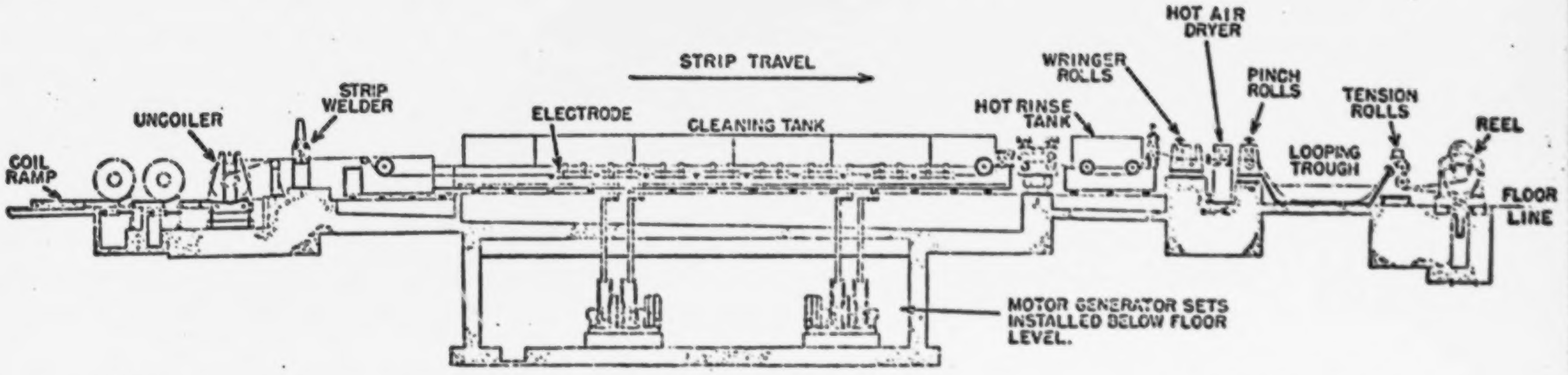
Annealing is heating a metal to its softening point and then cooling it slowly to room temperature. It relieves internal stresses in the material and is commonly applied to sheets, strip and tinplate, previously cold-reduced, i.e., rolled to the required gauge or thickness in their cold state. Unlike hot-rolling, cold reduction, while increasing the strength of the material, also reduces its ductility. This renders it unsuitable for some subsequent processings, such as galvanizing, tinning, etc., and heat treatment in the form of annealing is therefore applied which restores ductility by effecting changes in the mechanical properties of the material. Annealing is not, of course, necessary for hot-rolled products which are also used as a base for coating.

Until fairly recently the only annealing technique used for sheet or strip was box annealing (Studies C1 and D1) in which a large stationary mass of steel is subjected to a long heat-treating cycle by varying the temperature within the furnace which surrounds it. Box annealing equipment consists of bases on which the steel charge is placed, of inner covers, commonly painted with oxidation-rate reducing compounds, and of coal, oil or gas-fired box-shaped furnaces which are usually transportable so that they can be shifted to service several bases. As the newer, continuous annealing process described further incorporates electrolytic cleaning equipment, the box annealing process has here been considered jointly with the separate electrolytic cleaning process (Illus. 1 and 2) which precedes it; this makes the conventional and newer technology cases comparable.

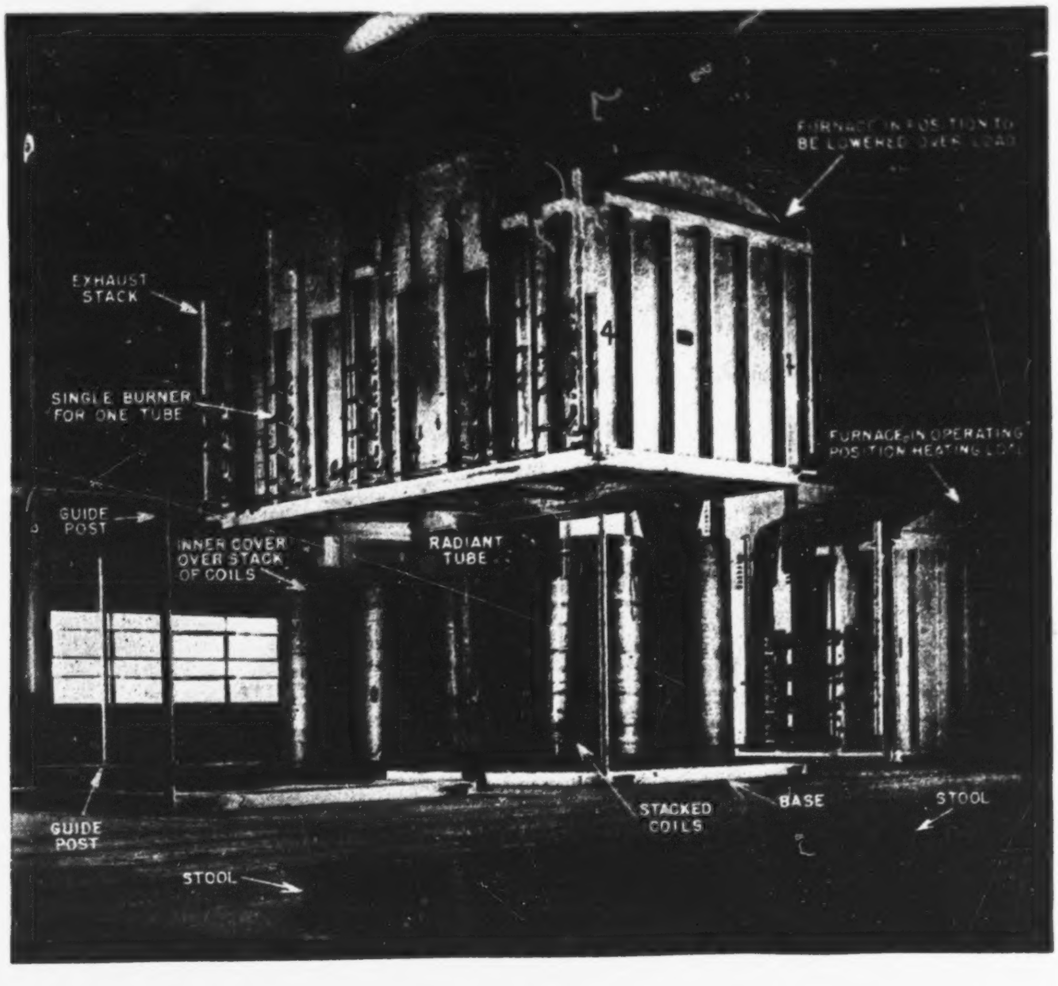
The first continuous annealing plant (Studies C2 and D2) was built in the U.S.A. as late as 1949. A single strip of steel, cold-reduced to a narrow gauge, travels at speeds up to 300 feet per minute through a set of furnaces providing a heating zone with a controlled temperature. The heat generated in the furnaces is intense enough to alter the mechanical structure of the steel strip in the relatively very short period during which the metal passes through them. Immediately following heat treatment the strip is cooled so that it emerges into the open cold enough for excess oxidation to be avoided.

A typical continuous annealing line consists of a double uncoiler onto which the incoming coils are loaded, a welding unit, an electrolytic cleaning bath and looping towers to take up or pay out strip and thus kepp it travelling at uniform speed, and the furnace proper with a heating tower and, next to it, a cooling tower. As the strip emerges from the cooling tower it passes through another looper and onto the take-up reel of recoiler. Interposed between the looper and the recoiler are shears for cutting the continuously oncoming strip after a given length of it has been wound onto the recoiler mandrel.

According to the managements in both works where the case studies were conducted continuous annealing should not at present be regarded as a full-fledged replacement of box annealing. Although for certain products the two processes can be used interchangeably, there is evidently still a range of others specifically requiring box annealing. In one of the steel works, in fact, new box annealing capacity is now being added.


HOT AIR DRYER
STRIP TRAVEL
WRINGER ROLLS
PINCH ROLLS
TENSION ROLLS
STRIP WELDER
UNCOILER
ELECTRODE
CLEANING TANK
HOT RINSE TANK
REEL
COIL RAMP
LOOPING TROUGH
FLOOR LINE
MOTOR GENERATOR SETS INSTALLED BELOW FLOOR LEVEL.

Illus.1: Schematic arrangement of a typical electrolytic cleaning line for processing cold-reduced steel.


FURNACE IN POSITION TO BE LOWERED OVER LOAD
EXHAUST STACK
SINGLE BURNER FOR ONE TUBE
FURNACE IN OPERATING POSITION HEATING LOAD
GUIDE POST
INNER COVER OVER STACK OF COILS
RADIANT TUBE
STACKED COILS
BASE
STOOL
GUIDE POST
STOOL

Illus.2: A 500-ton capacity annealing furnace for coils. The furnace is being lowered by crane over the base loaded with eight stacks of coils. The burner tubes may be seen extending across the interior of the furnace. Note guide posts at the corners of the base.

2. DESCRIPTIVE CHARTS OF ANNEALING AND ANCILLARY PROCESSES, FIRMS C & D

The charts in this section list and describe:

The Operation:	A discrete block of related tasks and activities.
The Operator(s):	Job titles of the operators who normally perform some or all of the duties connected with the operation are given separately for firm C and D.
The Equipment Used:	Main pieces of machinery used in the operations defined in column 1.
The Method:	Sequence of activities for performing the operations.
The Mode of Control:	Main aspects of operators' performance in controlling the material or processing machinery.
The Level of Mechanization:	The figures are based on a scale developed by J.R. Bright and describe the degree of functional autonomy built into the equipment used. A copy of this scale, giving definitions of the level numbers, precedes the charts.

Initiating Source	Type of Machine Response		Power Source	Level Number	LEVEL OF MECHANIZATION
From man	Variable		Manual	1	Hand.
				2	Hand Tool.
			Mechanical (Nonmanual)	3	Powered Hand Tool.
				4	Power Tool, Hand Control.
	Fixed within the machine			5	Power Tool, Fixed Cycle (single function).
				6	Power Tool, Program Control (sequence of fixed functions).
				7	Power Tool System, Remote Controlled.
From a variable in the environment	Responds with signal			8	Actuated by introduction of work piece or material.
				9	Measures characteristic of work.
				10	Signals preselected values of measurement. (Includes error detection)
				11	Records performance.
	Responds with action	Selects from a limited range of possible prefixed actions.		12	Changes speed, position, direction according to measurement signal.
				13	Segregates or rejects according to measurement.
				14	Identifies and selects appropriate set of actions.
		Modifies own action over a wide range of variation.		15	Corrects performance after operating.
				16	Corrects performance while operating.
				17	Anticipates action required and adjusts to provide it.

SEVENTEEN LEVELS OF MECHANIZATION AND THEIR RELATIONSHIP
TO POWER AND CONTROL SOURCES
(Reproduced from J.R. Bright, Automation and Management,
Boston: Harvard University, 1958, Exhibit 4-2, pg. 45)

Operation	C 1 Operator(s)	D 1 Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Charge Furnace i.e., stack coils on bases 4 high, position covers and furnace box.	Floorman + Annealing Craneman + Utility Man	Floorman + Process Craneman + Heat Treater Helper	Inner covers Box furnaces Slings Overhead traveling Shovel crane	Craneman positions coils on bases, floorman installs and connects thermocouples, Craneman places inner covers over charge, Floorman makes sand seal around cover, Craneman places box furnace over charge	Floorman's helper Verbal commands and direct manipulation. Craneman Control-levers and direct vision.	1,2,4
Start Furnace	Box Annealer Operator	Heat Treater + Heat Treater Helper	fixed furnace system Torch	Turns on motors, fans, and gases Lights burners	Manual Operation	2,5
Heat Treatment	Box Annealer Operator	Heat Treater + Heat Treater Helper	(fixed furnace system)	Observes recorders, adjusts fuel flow, adjusts air-gas ratios, etc. to maintain heating requirements. Makes tests to determine status of annealing atmosphere. Shuts off furnaces at end of firing cycle and allows coils to cool.	Manual regulation using instrumental readings	9
Unload	Stocker + Annealing Craneman + Utility Man	Floorman + Process Craneman + Heat Treater Helper	Inner cores Box furnaces Slings Crane	Team removes box furnaces, sand seal, inner covers. Craneman lifts coils from base and transports to next stage.	(as Charging)	1,2,4

C1, D1 BOX ANNEALING

Operation	C 1 Operator(s)	D 1 Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Load coil to mandrel, weld lead end of new coil to tail end of coil in process.	Coil Feeder-Welder + Coil Feeder Helper	Welding Machine Operator + Feeder	Mandrels (2) shears scrap box Welder (special-purpose heavy equipment)	Positions coil on mandrel Guides lead edge into shear Shear off defective material Guide lead edge into welder Weld coil ends	Manually actuated using electric power; push buttons and direct vision; some direct manipulation of strip.	1,5
Clean by chemical treatment; rinse and dry.	Coil Cleaner	Coiler + Strip Cleaner	Continuous treatment Tanks, Pumps, Condenser System, Rinsing and Drying Equipment.	Continuous flow treatment operator regulates speeds, temperatures, chemical composition for cleaning, rinsing and drying equipment.	Continuous running (automatic operation); manual regulation using buttons, etc.; status information from instruments.	9
Recoil strip after cleaning			Shear, Mandrels (2)	Starts new coil on mandrel; watches for arrival of weld, operates shear before and after weld; unloads coil from mandrel, prepares for next one.	(as Loading)	5,6
Weigh coil, upend and transport to Box annealing process.	Tractor Operator + Tow Tractor Operator	Tractor Operator	Scale, Tractor, Transfer cars, Upender	Moves coils from cleaning line to scale, upender, transfer cars and Box Annealing. Upends coil so that axis is vertical. Weighs coil and records weight.	(as Loading) and Tractor driving	4,5

C1, D1 BOX ANNEALING (Electrolytic Cleaning)

Operation	C 2 Operator(s)	D 2 Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Load Coil	Annealing Line Feeder	Coil Feeder (Welder)	Entry ramps Uncoilers (2) Mandrels ea. Inching rolls	Refer to production schedule and coil identity. Position coil on mandrel. Start coil through rolls.	Manually actuated electrically powered push-buttons and direct vision; some direct manipulation of strip.	1,5
Drop lead end and weld to tail of preceding coil.	Annealing Line Feeder	Coil Feeder (Welder)	Shear Automatic seam-welder	Crop and preposition lead end,stop strip near tail end of preceding coil,position Weld ends of successive coils together,restart strip;looping towers provide for continuous running of main line while this operation is carried out.	(as above) except no direct manipulation	5
Clean strip (continuous bath)	Annealing Line Operator + Ass't.Annealing Line Operator + Tractor Operator (Helper)	Annealing Line Operator + Ass't.Annealing Line Operator	titration apparatus electrolytic cleaning unit tanks scrubber	Takes titration tests of cleaning solutions. Checks and adjusts composition of electrolytic cleaner.	Manual adjustment of valves, etc., in response to test results.	5
Rinse, Wring, Dry (continuous)	Annealing Line Operator	Annealing Line Operator	Rinse tank Wringer Rolls Dryer	Checks levels and flow Sets temperatures	Manual adjustment of controls, etc., in response to instrumental readings.	5
Heat treatment (Annealing)	Annealing Line Operator + Ass't.Annealing Line Operator	Annealing Line Operator + Ass't.Annealing Line Operator	Heating towers Cooling towers Burners Thermostatic heat regulators, etc.	Checks & adjusts burners,tubes,heating elements,temperatures,pressures,etc.to secure desired rates of heating and cooling.	Manually preset temperatures regulated by automatic control.	1,2
Inspect strip, obtain samples for hardness test	Annealing Line Coiler	Coiler	Punch	Observes finished strip for shape,surface quality,foreign material, records quality.Removes hardness test samples by powered punch.	Direct visual observation and written recording.	1,5

(continued)

C2 , D2 CONTINUOUS ANNEALING

Operation	C 2 Operator(s)	D 2 Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Shear and Coil	Annealing Line Coiler	Coiler	Shear mandrels (2) footage counter	Stops strip at desired footage, operates shear, completes preceding coil, feeds lead end of strip into other mandrel, restarts strip, adjusts tension and speed.	(as Loading on preceding page)	5
Transport finished coil to storage area	Tractor Operator (Helper)	Annealing Line (Helper)	Tractor	Positions tractor to coil, picks up by inserting lifting arm, transports to storage area, unloads, returns.	Tractor driving, (control levers and direct vision)	4

(concluded)

C2 , D2 CONTINUOUS ANNEALING

3. CHARACTERISTICS OF TOTAL PRODUCT MIX AND OF PRODUCT SELECTED

To ensure comparability of the manhour/skill inputs between the two technologies, it was necessary to select from their respective product mixes one that was as nearly identical as possible. It would have been desirable for each product selected to conform to a second criterion, i.e., that it should be chosen from amongst those most frequently manufactured. This criterion could not always be met.

The tables in this section show the extent to which the products selected depart from the typical product of each technology along several critical dimensions.

TABLE II - 1

C1, BOX ANNEALING

	Product or Process Variables				
	End Tempers	Firing and Soaking times	Basis Weights	Widths	Furnace Capacities
Full range for all products	T1 - T6	Unobtainable	65 - 155	22 - 38	1.050.000 lbs. maximum capacity
Range for most frequent products	T4 , T5	28 - 30	90 - 100	32 - 35	480.000 lbs. (normal capacity)
Product selected	T4	29	100	32 - 35	448.000 lbs.

TABLE II - 2

C2, CONTINUOUS ANNEALING

	Product or Process Variables				
	End Tempers	Basis Weights	Gauges	Widths	Speeds of line
Full range for all products	T1 - T6	65 - 155	.007 - .019	22 - 38	900 - 1650 ft/Min
Range for most frequent products	T4 , T5	90 - 100	.00905 - .00960	32 - 35	1500 ft/min (maximum)
Product selected	T4	100	.0107 - .0114	32 - 35	1100 ft/min

TABLE II - 3

D1, BOX ANNEALING

	Product or Process Variables				
	End Tempers	Firing and Soaking Times	Basis Weights	Widths	Furnace Capacities
Full range for all products	T1 - T4	30 - 51	55 - 125	22 - 38	480.000 lbs. (maximum)
Range for most frequent product types	T3 , T4	40	75 - 95	32 - 36	300.000 - 320.000 lbs.
Product selected	T4	32	100	34	320.000 lbs.

TABLE II - 4

D2, CONTINUOUS ANNEALING

	Product or Process Variables				
	End Tempers	Basis Weights	Gauges	Widths	Speeds of line
Full range for all products	T4 - T6	55 - 125	.006 - .014	18 - 38	550 - 1250 ft/min
Range for most frequent product types	T5	75 - 95	.008 - .010	30 - 36	800 - 940 ft/min
Product selected	T4	100	.0105 - .0114	34	865 ft/min

4. METHOD OF DERIVING SKILL LEVEL VALUES FROM STEEL INDUSTRY JOB EVALUATION SCHEM

Agreement on a common job evaluation scheme was reached between the steel industry and the United Steelworkers during the war years and all jobs on all processes throughout the industry have since been assessed on the basis of twelve factors:

PRE-EMPLOYMENT TRAINING

EMPLOYMENT TRAINING AND EXPERIENCE

MENTAL SKILL

MANUAL SKILL

Responsibility for Material

Responsibility for Tools and Equipment

Responsibility for Operations

Responsibility for Safety of Others

Mental Effort

Physical Effort

Surroundings

Hazards

The first four factors were used to derive skill "scores" for all jobs on the annealing and coating processes at both technological levels.

Pre-employment training is defined as "the mentality required to absorb training and exercise judgement for the satisfactory performance of the job". Three discrete values are possible within the range 0 - 1.0.

Employment training and experience - definition: "Time required to learn how to do the job satisfactorily. This includes time spent on directly related work and on the specified jobs". Number of discrete values possible: 9, in the range 0 - 4.0.

Mental skill - definition:"Mental ability, job knowledge, judgement, and ingenuity required to visualize, reason through and plan the details of a job without recourse to supervision". Number of discrete values possible: 6, in the range 0 - 3.5.

Manual skill is defined as "physical or muscular ability and dexterity required in performing a given job including the use of tools, machines and equipment". Number of discrete values possible: 5, in the range 0 - 2.0.

The range for the employment training and experience factor is greatest, followed by the mental skill range. These two factors thus carry most weight when the points are added for any given jobs to yield a total skill "score".

5. RAW DATA USED FOR THE DEVELOPMENT OF SKILL PROFILES

These data are tabulated under the title of each process, with the volume of product processed per shift in parentheses. The following notes explain the meaning of each column in the tables:

Job Code:	The codes are internal codes, assigned to each job to facilitate cross referencing. The letter identifies the firm, the attached figure identifies technology and the figure separated by a dash, the job.
Job D.O.T. Number:	These six digit numbers are taken from the 1965 edition of the Dictionary of Occupational Titles. The matching of D.O.T. Number and job was done by the researchers on the basis of job description and their own knowledge of the jobs.
Job Title:	Official titles assigned to the jobs by the firm.
Skill Level:	Total skill factor points derived from the job evaluation scheme operative throughout the steel industry.
Manhours:	Determined from crew requirements established by the firm and from discussions with personnel familiar with the operations.
Volumes:	Determined by reference to operating specifications and product dimensions (e.g., speed, firing time, width of product, etc.) and checked with the firms' Industrial Engineering personnel.

FIRM C: ANNEALING

C1 BOX ANNEALING

Electrolytic Cleaning Line (Volume: 239.4 tons per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift
C1-2	613.885 613.782	Coil Feeder Welder	2.5	8
C1-3	613.885	Coil Feeder Helper	2.5	8
C1-5	929.883	Tractor Operator	2.8	8
C1-11	613.782	Coil Cleaner	4.7	8

Box Annealing Process (Volume*: 14,784 - 17,248 tons per week)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Week	Tons Per Week*
C1-1	626.884	Utility Man	1.0	160	17,248
C1-4	892.883	Stocker	2.7	320	17,248
C1-6	929.883	Tow Tractor Operator	2.8	120	17,248
C1-7	929.883	Utility Tractor Operator	2.8	5	17,248
C1-8	922.887	Floorman (Packer)	3.2	160	14,784
C1-9	921.280	Annealing Craneman	3.2	320	14,784
C1-10	504.782	Furnace Operator - Box Annealing	4.2	168	17,248

*Within a certain range of tons per week produced, there are no commensurate reductions in man hours because operators are assigned for a range of furnaces in operation. For example, two Annealing Cranemen (C1-9) are required whether only 6 or as many as 12 furnaces are operating. The volume shown for each job reflect the maximum number of furnaces operating for the corresponding manhours.

C2 CONTINUOUS ANNEALING (Volume: 325.2 tons per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift
C2-1	929.883	Helper-Continuous Strip Annealing (Tractor Operator)	2.8	8
C2-2	929.883	Stocker-Tractor Operator	2.8	4
C2-3	851.883	Utility Tractor Operator	2.8	0.25
C2-4	613.885 613.782	Annealing Line Feeder	3.2	8
C2-5	613.885 613.782	Annealing Line Coiler	3.2	8
C2-6	504.782	Assistant Annealing Line Operator	4.2	8
C2-7	504.782	Annealing Line Operator	5.3	8

FIRM D: ANNEALING

D1 BOX ANNEALING

Electrolytic Cleaning Line (Volume: 337 tons per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift
D1-1	613.885 613.782	Feeder	1.9	8
D1-3	613.782	Welding Machine Operator	2.5	8
D1-4	929.883	Tractor Operator	2.8	2
D1-5	929.883	Tractor Operator	2.8	8
D1-8	613.885 613.782	Coiler	3.7	8
D1-10	503.782	Strip Cleaner	5.8	8

Box Annealing Process (Volume: 240 tons per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift
D1-2	626.884	Packer (Floorman)	1.9	8
D1-6	504.885	Furnace Man	3.2	8
D1-7	921.280	Process Craneman	3.2	6
D1-9	504.782	Annealer	5.7	8

D2 CONTINUOUS ANNEALING (Volume: 241.5 tons per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift
D2-1	504.885	Annealing Line Helper	2.8	8
D2-2	613.885 613.782	Coil Feeder Welder	3.2	8
D2-3	613.885 613.782	Coiler	3.2	8
D2-4	504.131	Assistant Annealing Line Operator	4.2	8
D2-5	504.131 504.281	Annealing Line Operator	5.3	8

6. LENGTH OF OPERATORS' GENERAL EDUCATION AND ON-THE-JOB EXPERIENCE

The internal job codes and job titles used in section 5 are retained to facilitate cross referencing.

Estimates of general educational requirements made by researchers.

Estimates of on-the-job experience requirements supplied by firms.

FIRM C: ANNEALING

Job Code	Job Title	Estimated Required General Education (Years of High School)			On-the-job Experience (Months)					
		0	1-2	3-4	0-2	3-6	7-12	13-18	19-24	25-30
C1 BOX ANNEALING										
Electrolytic Cleaning Line (Volume: 239.4 tons/shift)										
C1-2	Coil Feeder Welder	X				X				
C1-3	Coil Feeder Helper	X				X				
C1-5	Tractor Operator	X				X				
C1-11	Coil Cleaner		X					X		
Box Annealing Process (Volume: 14,784 - 17,248 tons/week										
C1-1	Utility Man	X			X					
C1-4	Stocker		X				X			
C1-6	Tow Tractor Operator	X				X				
C1-7	Utility Tractor Operator	X				X				
C1-8	Floorman (Packer)		X				X			
C1-9	Annealing Craneman	X						X		
C2 CONTINUOUS ANNEALING (Volume: 325.2 tons/shift)										
C2-1	Helper-Continuous Strip Annealing (Tractor Operator)	X				X				
C2-2	Stocker-Tractor Operator	X				X				
C2-3	Utility Tractor Operator	X				X				
C2-4	Annealing Line Feeder	X					X			
C2-5	Annealing Line Coiler	X					X			
C2-6	Assistant Annealing Line Operator		X					X		
C2-7	Annealing Line Operator			X					X	

FIRM D: ANNEALING

Job Code	Job Title	Estimated Required General Education (Years of High School) 0	1-2	3-4	On-the-job Experience (Months) 0-2	3-6	7-12	13-18	19-24	25-30
D1 BOX ANNEALING										
Electrolytic Cleaning Line (Volume: 337 tons/shift)										
D1-1	Feeder	X				X				
D1-3	Welding Machine Operator	X				X				
D1-4	Tractor Operator	X				X				
D1-5	Tractor Operator	X				X				
D1-8	Coiler	X					X			
D1-10	Strip Cleaner		X						X	
Box Annealing Process (Volume: 240 tons/shift)										
D1-2	Packer (Floorman)	X				X				
D1-6	Furnace Man		X				X			
D1-7	Process Craneman	X					X			
D1-9	Annealer		X							X
D2 CONTINUOUS ANNEALING (Volume 241.5 tons/shift)										
D2-1	Annealing Line Helper	X				X				
D2-2	Coil Feeder Welder	X					X			
D2-3	Coiler	X					X			
D2-4	Assistant Annealing Line Operator		X					X		
D2-5	Annealing Line Operator			X					X	

7. ANALYSIS OF VARIANCE LAYOUT OF DATA AND DETAILED SUMMARY

Improved estimate of residual variance was obtained by pooling the sums of squares and the degrees of freedom of the original residual estimate and of the T x F interaction.

The mean squares of the SL x T and SL x F interactions and of the main effects were tested against this improved estimate.

Key to abbreviations:

D.F. - Degrees of freedom

S.S. - Sums of squares

M.S. - Mean squares

V.R. - Variance ratio

SL - Skill levels

T - Technology levels

F - Firms

TABLE II - 5

Manhours per unit product classified by skill level, firm and technology

Skill Level	Technology 1		Technology 2	
	Firm 1 (C1)	Firm 2 (D1)	Firm 1 (C2)	Firm 2 (D2)
Low	0.09	0.00	0.00	0.00
Medium	1.59	1.69	0.87	0.99
High	0.43	0.81	0.49	0.66
Totals	2.11	2.50	1.36	1.65

TABLE II - 6

Analysis of Variance Summary

Source of Variance	D.F.	S.S.	M.S.	V.R.	Significance Level
Between skill levels	2	3.20	1.60	228.57	$P < 0.001$
Between technologies	1	0.21	0.21	30.00	$P < 0.05$
Between firms	1	0.04	0.04	5.71	
SL x T	2	0.30	0.15	21.40	$P < 0.05$
SL x F	2	0.05	0.03	4.30	
T x F	1	0.00	0.00		
Residual	2	0.02	0.01		
Improved residual estimate	(3)	(0.02)	(0.007)		
Total	11	3.82			

8. JOB DESCRIPTIONS

C1: Box annealing including Electrolytic Cleaning

Each job title is preceded by the internal job code. The number to the far right is the skill factor point rating for the job.

Cl-1 - Utility Man 1.0

Assists crane man in the performance of his duties and hooks, unhooks and positions material and equipment transported by cranes in annealing department. Inspects inner covers on furnace bases after furnace is removed to detect leaks.

Cl-2 - Coil Feeder Welder 2.5

Operates controls on all equipment at the entry end of the electrolytic cleaning line, i.e. ramp stop controls, blocker roll controls, shear controls, controls to collapse mandrel to position and shear tail end of strip in line, to advance head end of loose strip into welder, to clamp and weld strips, and to shift position of uncoiler. Assists in threading, adjusting and repairing line. Acts as hooker when crane is used to place collapsed coils on uncoiler.

Cl-3 - Coil Feeder Helper 2.5

Prepares coils and assists in feeding strip and in discharging clean coils. Inspects tanks for leaks, solution level, temperature reading, and scrubber brush ampères and reports any non-standard condition to operator. Maintains proper solution levels and temperatures. Operates up-tilter controls and electric spot welding equipment. Assists in threading, adjusting, and repairing line. Operates speed and tension controls when operator is engaged on line.

Cl-4 - Stocker 2.7

Stocks coils to storage after annealing. Maintains current inventory of coils in storage. Locates coils for transfer to Temper Mill Bay and assists crane man in unloading operations. Acts as crane hooker in loading and unloading flat sheets or wire for annealing. Inspects inner covers on furnace bases after furnace is removed to detect leaks.

Cl-5 - Tractor Operator 2.8

Operates fork-lift tractor to transport coils from electrocleaning to transfer car or to storage. Assists in removing wraps from eyes of coils and operates welding equipment to spot-weld coil wraps, identification plates and strap.

Cl-6 - Tow Tractor Operator 2.8

Operates industrial type tow tractor to transport coils from four-stand mill to annealing department and continuous coating line, from electrocleaners to annealing department and within annealing department.

Cl-7 - Utility Tractor Operator 2.8

Operates tractor in hauling supplies to and from the continus pickler, five-stand tandem mill and electrocleaner; and manually loads and unloads supplies when required.

C2: Continuous Annealing

Each job title is preceded by the internal job code. The number to the far right is the skill factor point rating for the job.

C2-1 - Tractor Operator (Plant job title: Helper-Continuous Strip Annealing Line) 2.8

Checks cleaner solution concentration, brushes, meters, seals, etc. Makes additions to cleaner when necessary. Operates up-cut shear to shear scrap to charge-box size. Assists in adjustments and breakdowns and in starting up and shutting down the line. Operates tractor to transport coils, empty scrap boxes, to change cleaning powder boxes, to move scrap to scrap storage area, and to weigh coils for testing purposes, etc.

C2-2 - Tractor Operator (Plant job title: Stocker- Tractor Operator Continuous Strip Annealing Line) 2.8

Operates tractors to service continuous strip annealing line and to maintain an orderly arrangement of material in the storage area.

C2-3 - Utility Tractor Operator 2.8

Identical with job description for C1-7.

C2-4 - Annealing Line Feeder 3.2

Charges and welds coils in scheduled sequence to the continuous strip annealing line. Obtains and removes test samples as directed. Assists in adjustments and breakdowns and in starting up and shutting down the line.

C2-5 - Annealing Line Coiler 3.2

Shears the strip and operates controls to discharge coils from line. Starts new coils in re-coiler, trims coils and tack welds coil identity disks. Observes finished strip for oxide discoloration or oil from reels, and for scratches. Assists in starting up and shutting down line and on adjustments and breakdowns. Obtains Rockwell test samples. Performs tractor work as required. Compiles production, delay, and special study reports.

C2-6 - Assistant Annealing Line Operator 4.2

Assists the operator in the overall line operation and operates electrolytic cleaner, heating and holding furnaces and cooling chamber on the continuous annealing line. Directs and/or assists crew in starting up and shutting down the line. Directs and/or assists on strip breaks and breakdowns in general. Records operating data. Directs and/or performs tests to insure quality product. Operates tractor as required.

C2-7 - Annealing Line Operator 5.3

Checks turn production schedules. Directs and/or assists in maintaining determined line speeds, furnace temperatures, atmospheric conditions, cleaner concentrations, etc. Checks equipment at all levels. Directs and assists crew in the starting up and shutting down of the line and on strip breaks and breakdowns. Maintains contact with the annealing gas systems attendant on consumption of atmospheric gas. Records operating data. Directs and/or performs tests to insure quality product. Operates tractor as required.

D1: Box Annealing including Electrolytic Cleaning

Each job title is preceded by the internal job code. The number to the far right is the skill factor point rating for the job.

D1-1 - Feeder 1.9

Assists welder to prepare coils for entry into cleaning line. to operate controls, to adjust equipment and to repair strip breaks. Checks accuracy of scale.

D1-2 - Floorman (Plant title: Packer) 1.9

Assists furnace man in preparing, loading and unloading coils. Guides crane man. Makes up furnace loads and submits to annealer for approval. Records and maintains records of coils on bases and in storage.

D1-3 - Welding Machine Operator 2.5

Operates equipment to feed and weld coils at entry end of electrolytic cleaning line. Assists in operating controls and adjusting equipment. Participates in repairing strip breaks, threading line, removing twists and cobbles and placing scrap in containers.

D1-4 - Tractor Operator 2.8

Operates electrically controlled tractor to transport cold reduction, pickle line, continuous annealing line, and electrolytic cleaning line material in tin mill. Checks tractor for operating efficiency.

D1-5 - Tractor Operator 2.8

Operates electrically controlled tractor to transport electrolytic cleaning line and box annealing product in the tin mill. Operates down-ender and up-ender. Performs hooking duties when required.

D1-6 - Heat Treater Helper (Plant title: Furnace Man) 3.2

Assists annealer in the operating of annealing furnaces, bases, and auxiliary equipment, recording information as to temperatures, solution concentration, etc. and loading and unloading coils on bases. Records and maintains identity of coils in annealing furnaces and storage areas on standard forms or by teletype. Performs various tests. Participates in purging bases, moving furnaces and inner covers, sanding inner covers, loading, preparing and unloading coils, placing and removing spacers, straightening inner covers, spraying inner covers, etc.

D1-7 - Process Craneman 3.2

Operates overhead crane to transport material and equipment in the box annealing area and for maintenance crews while repairing and replacing equipment.

D1-8 - Coiler 3.7

Operates equipment for cleaning, coiling, and removing coils at exit end of electrolytic cleaning line. Adjusts guides, rolls, screw-downs, air sprays, tension coilers, etc. Participates in repairing strip breaks, threading line, removing twists and cobbles and placing scrap in container.

D1-9 - Heat Treater (Plant title: Annealer) 5.7

Directs and is responsible for the operation of the annealing furances and auxiliary equipment. Directs maintenance of inventory records of material in the annealing area and identification and processing treatment on standard forms. Makes up maximum furnace loads of the same orders and treatment. Checks chart readings and instruments for furnace and steel temperature, time and gas and air pressure. Regulates controls during annealing cycle to insure prime quality product. Directs and works with crew in purging bases, moving furnaces, sanding inner covers, preparing, loading and unloading coils, operating cover straightener, spraying inner covers, etc.

D1-10 - Strip Cleaner 5.8

Directs the operation of the electrolytic cleaning line. Checks production schedules for specifications on material to be cleaned and directs crew as to sequence of production. Runs test coils. Maintains and adjusts bath concentration and required solution mixtures and levels in tanks. Maintains identity of coils, records chemical additions, solution changes, titration results, and other data on standard forms. Directs and participates in adjusting equipment and inspects equipment for necessary repairs and replacements. Operates and directs crew to operate controls. Directs and participates in repairing strip breaks, threading line, removing twists and cobbles and placing scrap into containers. Weighs and records weight of coils on tags.

D2: Continuous Annealing

Each job title is preceded by the internal job code. The number to the far right is the skill factor point rating for the job.

D2-1 - Annealing Line Helper 2.8

Operates tractor to service line and assists in starting up and shutting down the line. Performs necessary duties on strip breaks, threading line, removing cobbles, etc.

D2-2 - Coil Feeder Welder 3.2

Operates equipment to feed and weld coils in scheduled sequence at entry end of continuous annealing line. Controls line speed during welding operation and during operating or material irregularities. Makes adjustments to achieve proper strip tracking. Inspects strip for bad edges, breaks, etc. Performs necessary duties on strip breaks, threading line, removing cobbles, etc.

D2-3 - Coiler 3.2

Operates equipment for re-coiling and discharging coils from the continuous annealing line. Observes finished strip for shape and surface and reports to the annealer. Weighs discharged coils from exit end of continuous annealing line and records weight on production report and on coil. Obtains Rockwell test samples as required and makes out and maintains necessary records and reports. Performs necessary duties on strip breaks, threading line, removing cobbles, etc.

D2-4 - Assistant Annealing Line Operator 4.2

Assists the annealer in setting up, starting, and operating the continuous annealing line and auxiliary equipment. Directs and/or assists crew members in the performance of their duties. Checks equipment at all levels and makes necessary adjustments. Performs necessary duties on strip breaks, threading line, removing cobbles, etc. Records operating data on standard form.

D2-5 - Annealing Line Operator 5.3

Checks production schedules for specifications on material to be annealed. Directs crew as to sequence of production. Starts up line and assumes responsibility for the operation of the continuous annealing line and auxiliary equipment. Directs and/or assists crew members in the performance of their duties. Checks equipment at all levels and directs and/or assists the crew in making necessary adjustments. Performs necessary duties on strip breaks, threading line, removing cobbles, etc. Maintains records of coil identity, solution levels, chemical additions, titration tests, furnace and steel temperatures, tension regulation, regulation of furnace controls, and necessary records of other pertinent data on standard forms. Contacts gas supplier on items relating to volume and quality of atmosphere gas supplied. Determines and reports necessary repair work to supervision or responsible maintenance personnel.

APPENDIX III

STEEL

Sheet and Continuous Coating
of Steel Strip

APPENDIX III

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1. OUTLINE OF TECHNOLOGIES

For reasons previously mentioned the initial study of galvanizing could not be directly replicated for lack of a suitable site and the closely comparable process of tinning was chosen instead. As will be evident from the subsequent descriptions, the processes are broadly similar, both in their older versions and in the newer.

Galvanizing is the cheapest and most common method of coating steel strip surfaces to prevent corrosion. The coating metal is commercial zinc (spelter) which is applied by passing steel sheets or strip through a molten zinc bath. The thickness of the coating, its quality and uniformity, and the thoroughness of adhesion are affected by a large number of critical variables which have to be maintained within narrow tolerance limits during processing. The essential prerequisite for the successful application of a zinc coating (and of all other coatings) is the complete freedom of the steel surfaces from oxides, rust, or foreign materials: to achieve this, the sheets are as a rule first passed through an acid bath prior to galvanizing, a process termed pickling, which includes rinsing in hot or cold water. For a few end-products pickling is omitted, and instead the sheets or strip are dipped in a hydrochloric acid bath which forms part of the galvanizing lines. In the case studies discussed here the pickling and rinsing processes have not been included.

The older process of hot-dip galvanizing (Study C3) has survived only because some of the steel sheeting ordered by customers was of too heavy a gauge to be acceptable to the continuous galvanizing line. Because the heavy gauge material comes directly from the hot-strip mill, it requires no annealing; however, it must first be cut into sheets on a cut-up line. The stacks of sheets are transported from the shear line to the feeding table of the galvanizing line, and are then fed one by one into the hydrochloric acid cleaning tank. The rest of the equipment consists of the zinc coating pot the spangle conveyor, the cooling conveyor overhung by an air blower device, of a water bath, a dryer, a roller leveller, a rotating "porcupine" rack and an inspection table. Illustration 3 shows the equipment in diagrammatic form.

When sheet steel became available in coil form, continuous galvanizing processes (Study C4), which allow considerable economies in operation as well as improvements in the quality and uniformity of the end product, began rapidly to supplant the cumbersome and slow hot-dip process; similar developments also took place with other coating and finishing processes.

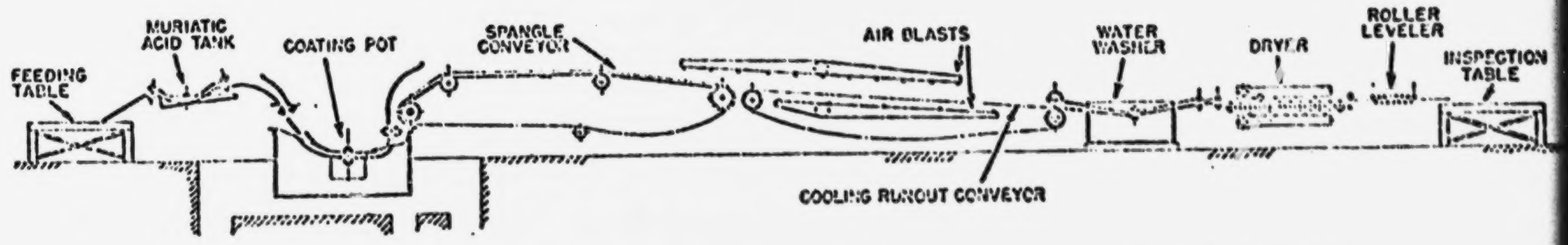
The initial problems connected especially with the handling of coiled material now appear to have been resolved, but due to the high speed with which the strip travels through the complex installation a high degree of integration in the operating teams is essential. The continuous galvanizing lines (Illustration 4) comprise annealing furnaces in addition to acid cleaning baths and have looping towers which allow the line to run continuously while the incoming end is stopped for welding on the next reel. Otherwise the equipment is similar in name and function to that on the older hot-dip line.

Tinning, like galvanizing, is a coating process intended to provide resistance to corrosion and protection against the adverse effects of numerous acids. Tin, though more expensive than zinc, is still relatively cheap, gives a pleasing surface appearance and has been found to be the ideal coating for the thin gauge steel strip used in the fabrication of cans, some kitchen utensils, some kinds of electrical equipment components, toys, etc. Because it is more difficult to achieve secure adhesion of tin than it is of zinc, the preparation of the base material for tinning is lengthy and highly critical throughout. To achieve the thin gauge required, the steel strip must be cold reduced; it is then electrolytically cleaned, annealed, temper-rolled and levelled.

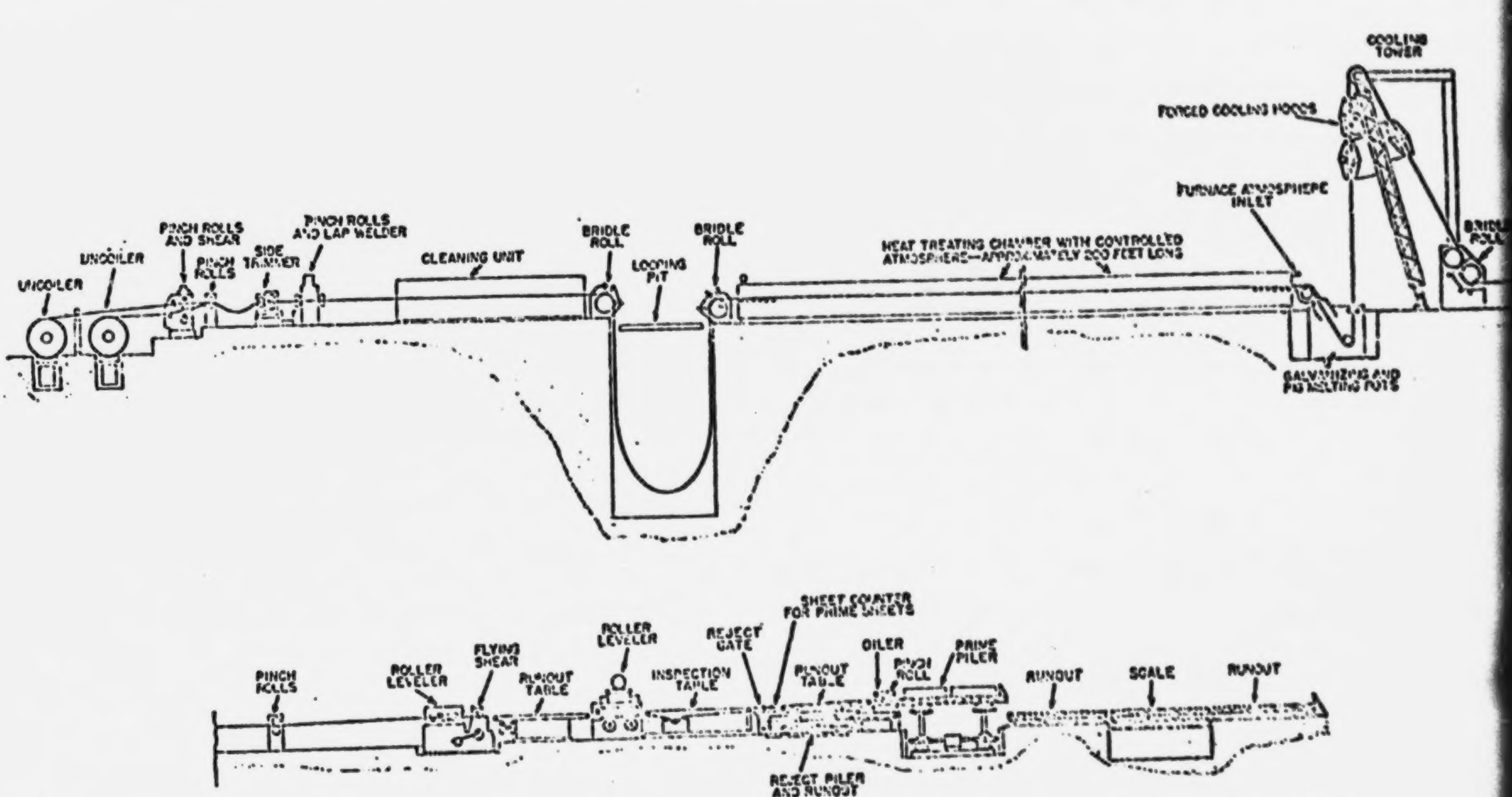
The older process of hot-dip tinning (study D3), universally employed until 1937. has now almost completely disappeared. The newer electrolytic plating processes not only produce superior uniformity of coating but they are more economical in their usage of tin; substantial savings have also been achieved by making the process continuous.

For hot-dip tinning the continuous strip that had previously been cleaned, annealed, tempered and levelled must be cut up into sheets, and the shear line has therefore been included in the present study. The stacked sheets are placed on a feeder device at the entry end of the line, whence they pass consecutively through a cleaning tank, the tin pot and tinning machine, a wet washing machine and a branner, where a regularly replenished supply of bran distributes a light oil film evenly over the sheet surface; finally the sheets enter the piler (see also Illustration 5).

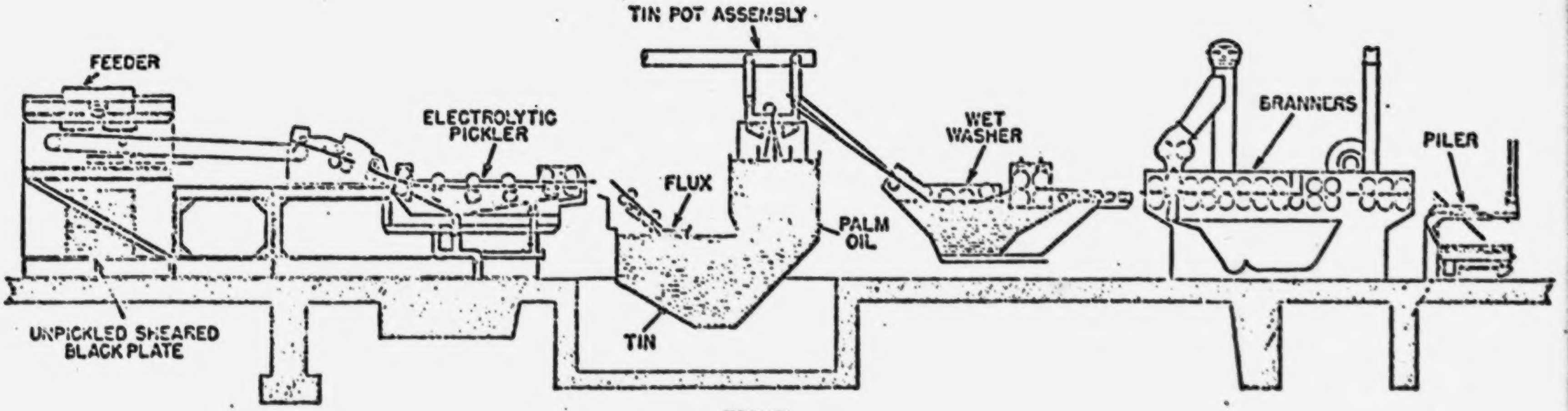
Continuous electrolytic tinning (study D4), which represents the more advanced technology, differs in principle from its predecessor: the coating is applied not by dipping but by electrolytic action. Operationally however there is little difference as the processing in the electrolytic plating bath requires hardly any more regulation than would a dip bath (cf. continuous galvanizing). In its construction, too, a modern electrolytic tinning line resembles a continuous galvanizing line: after loading on the uncoiler, the product passes successively through a welder, a looping tower, a cleaning tank and a rinser, a strip pickling unit, the actual plating tanks, followed by a melting unit where the coating is melted and quenched so that it acquires a brilliant luster, and an emulsion oiler; at the far end of the line are recoilers, flying shears and pilers. The equipment is shown in Illustration 6.


FEEDING TABLE
MURIATIC ACID TANK
COATING POT
SPANGLE CONVEYOR
AIR BLASTS
WATER WASHER
DRYER
ROLLER LEVELER
INSPECTION TABLE
COOLING RUNOUT CONVEYOR

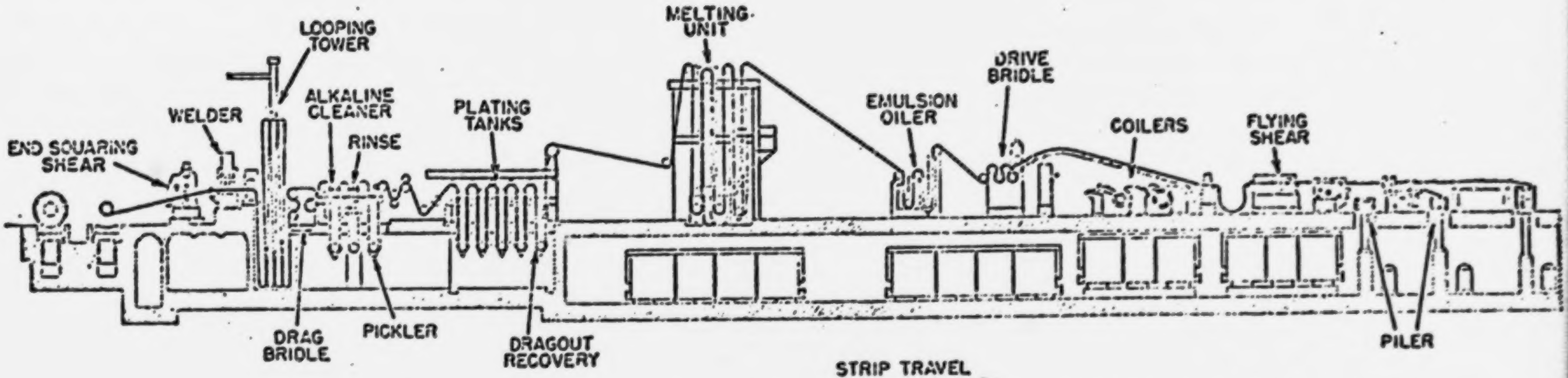
Illus.3: Schematic side elevation of a conventional sheet galvanizing line.


UNCOILER
UNCOILER
PINCH ROLLS AND SHEAR
PINCH ROLLS
SIDE TRIMMER
PINCH ROLLS AND LAP WELDER
CLEANING UNIT
BRIDLE ROLL
LOOPING PIT
BRIDLE ROLL
HEAT TREATING CHAMBER WITH CONTROLLED ATMOSPHERE—APPROXIMATELY 200 FEET LONG
FURNACE ATMOSPHERE INLET
FORCED COOLING HOODS
COOLING TOWER
GALVANIZING AND PIG MELTING POTS
PINCH ROLLS
ROLLER LEVELER
FLYING SHEAR
RUNOUT TABLE
ROLLER LEVELER
INSPECTION TABLE
REJECT GATE
SHEET COUNTER FOR PRIME SHEETS
RUNOUT TABLE
OILER
PINCH ROLL
PRIME PILER
RUNOUT
SCALE
RUNOUT
REJECT PILER AND RUNOUT

Illus.4: Schematic arrangement of a modern continuous galvanizing line for applying zinc coatings to cold-reduced light-gauge strip steel. The steel is fed from the uncoilers into the line, successive strips being welded at their ends to provide an uninterrupted feed. The top part of the diagram shows in succession (left to right) the feeding, cleaning, heat treating and coating stations. The bottom part shows the finishing end of the line.


TIN POT ASSEMBLY
FEEDER
ELECTROLYTIC PICKLER
FLUX
PALM OIL
WET WASHER
BRANNERS
PILER
UNPICKLED SHEARED BLACK PLATE
TIN
TRAVEL

Illus.5: Schematic arrangement of a hot-dip tinning stack.


LOOPING TOWER
MELTING UNIT
DRIVE BRIDLE
EMULSION OILER
ALKALINE CLEANER
WELDER
PLATING TANKS
COILERS
FLYING SHEAR
END SQUARING SHEAR
RINSE
DRAG BRIDLE
PICKLER
DRAGOUT RECOVERY
PILER
STRIP TRAVEL

Illus.6: Schematic arrangement of a sulpnonic acid electrolytic tinning line.

2. DESCRIPTIVE CHARTS OF COATING (GALVANIZING AND TINNING) AND ANCILLARY PROCESSES, FIRMS C & D

The charts in this section list and describe:

The Operation:	A discrete block of related tasks and activities.
The Operator(s):	Job titles of operators who normally perform some or all of the duties connected with the operation.
The Equipment used:	Main pieces of machinery used in the operations defined in column 1.
The Method:	Sequence of activities for performing the operations.
The Mode of Control:	Main aspects of operators' performance in controlling the material or processing machinery.
The Level of Mechanization:	The figures are based on a scale developed by J.R. Bright and describe the degree of functional autonomy built into the equipment used. A copy of this scale, giving definitions of the level numbers, precedes the charts.

Initiating Source	Type of Machine Response		Power Source	Level Number	LEVEL OF MECHANIZATION
From a variable in the environment	Responds with action	Modifies own action over a wide range of variation.	Mechanical (Nonmanual)	17	Anticipates action required and adjusts to provide it.
				16	Corrects performance while operating.
				15	Corrects performance after operating.
		Selects from a limited range of possible prefixed actions.		14	Identifies and selects appropriate set of actions.
				13	Segregates or rejects according to measurement.
				12	Changes speed, position, direction according to measurement signal.
	Responds with signal			11	Records performance.
				10	Signals preselected values of measurement. (Includes error detection)
				9	Measures characteristic of work.
				8	Actuated by introduction of work piece or material.
	Fixed within the machine			7	Power Tool System, Remote Controlled.
				6	Power Tool, Program Control (sequence of fixed functions).
				5	Power Tool, Fixed Cycle (single function).
From man	Variable			4	Power Tool, Hand Control.
				3	Powered Hand Tool.
			Manual	2	Hand Tool.
				1	Hand.

SEVENTEEN LEVELS OF MECHANIZATION AND THEIR RELATIONSHIP

TO POWER AND CONTROL SOURCES

(Reproduced from J.R. Bright, Automation and Management, Boston: Harvard University, 1958, Exhibit 4-2, pg. 45)

Operation	Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Load onto mandrel	Coil Feeder	Coil conveyor Coil shunter Mandrels Pinch rods and loop guides (Trimmer) Looper	Refer to production order. Position coil on mandrel. Guide coil between rods, through tinner, to shear.	Manually actuated, using electric power; push-buttons and direct vision; some direct manipulation of strip.	1,4,5
Shear into sheet lengths, flatten	Flying Shearman Shearman	Roller Leveller (a train of paired rolls on a flat bed) Flying shear	Sets shear for desired length. Stops and starts shearing line; sets and resets leveller.	Automatic cycle after initial set-up; monitors and adjusts action of leveller.	5
Inspection, sorting and disposal of rejects.	Assorter	Conveyor Roller/Leveller Inspection table Reject piles Stenciller	Inspects sheets for defects. Signals end of lift by reference to production order and mechanical counter. Operates reject piler and records defects. Changes stencils.	Direct visual inspection; manipulates material by use of push-buttons.	5
Piling	Piler	Separates blocks Prime piler table Roller conveyors Oiling unit	Separates lifts. Operates prime piler to stack sheets. Removes lifts of rejects. (Operates oiler for sheets to be stored)	Inserts blocks manually, otherwise as loading.	5

(continued)

C3: SHEARLINE (Prior to Sheet Galvanizing)

Operation	Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Weigh and band each lift	Wrapper and Weigher	Conveyor Scales	Applies band, transfers lift to scale-platform, operates print-weigh scale. Records results.	Applies band manually otherwise as loading.	2,4
Transport to galvanizing line	Galvanizing craneman and Hooker	Overhead travelling crane. Hook Slings.	Operates crane to pick up lifts and transport to galvanizing area. Moves lifts to feed-table. Signals to craneman. Hooks and unhooks load.	As loading and crane driving (direct visual control)	4

(concluded)

C3: SHEARLINE (Prior to Sheet Galvanizing)

Operation	Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Feeding sheets into grab rollers	Sheet feeder	Feed table	(Pile of sheets deposited on table) Picks up sheets one by one and pushes between rolls to maintain continuous flow. Raises feed table from time to time, lowers for new pile.	Direct manipulation using tongs; push button to operate feed table.	5
Cleaning Coating Washing Drying Levelling of sheets (sheets passed through bath of molten zinc by means of a guid	Potman	Cleaning tank Coating pot Spangle conveyor Cooling unit and conveyor Washer Drier Leveller Speed control unit	Monitors acid concentration. Ensures coating quality and uniformity by making proper additions to pot. Regulates speed of line and proper operating conditions of washing, drying, levelling and other equipment.	(continuous running automatic operation) Direct visual inspection; additions to pot made manually; push buttons and	6
Removal of excess zinc on sheet edge (sheets lifted from both by conveyor, passed to spangler)	Assorter Helper (Wiper)	Spangle Conveyor	Removes excess zinc from sheet edge after emergence from pot and prior to spangle formation.	Hooked wiping rod drawn manually across left edge.	2
Transportation during cooling, insertion in porcupine cooling rack	None	Conveyor Porcupine rack	- -	- -	5
Restacking Inspection and Stencilling of sheets	Assorter and Assorter Helper	Porcupine rack Hand stencil kit	Removes sheets from (porcupine) cooling rack. Inspects both sides. Restacks. Applies stencils.	Push buttons and to advance pack, visual inspection; sheets turned, stacked and stencilled manually.	2,5

C3: SHEET GALVANIZING

Operation	Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Load coil to mandrel	Coil Feeder	Coil shunter Mandrels(2) Pinch rolls (2) Shear Welder (Trimmer) Looping installation	Refers to production order. Positions coil on mandrel. Shears off lead end of coil and and removes scrap. Shears off tail end of previous coil and removes scrap. Welds lead end and tail end together. Starts strip through mill. Watches for lap welds.	Manually actuated using electric power; push-buttons used with direct visual control; some direct manipulation of strip.	5
Continuous cleaning, annealing of strip	Continuous Galvanizer Operator	Continuous strip-cleaning units, Heat treatment and cooling chambers, instrumentation, automatic recorder/ controllers.	Monitors status of process and makes adjustments to process variables. Refers to dials, recorders, closed circuit TV screens etc.	Continuous running (automatic operation) with manual regulation using push-buttons, etc. Status information from instruments.	9,11,12
Continuous coating of strip	Assistant Continuous Galvanizer Operator	Continuous strip-coating for coating rolls, Cooling towers Cooling hoods Zinc premelting furnace	Regulates levels, concentration and temperature of zinc in premelt furnace and zinc pot. Checks condition of processing equipment, and of product.	as above	5
Stencil, level and shear strip	Shearman + Assorter	Stenciller (automatic) Roller levelers conveyors Flying shear Runout tables Reject piler	Replenishes ink in stenciller Sets flying shear for desired length Inspects sheets for surface defects Operates reject piler and records	Direct visual inspection, push-bottons to operate pilers, etc.	5

(continued)

C4: CONTINUOUS GALVANIZING

Operation	Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Pile sheets	Sheet Piler	Separator blocks Prime piler Roller conveyors	Separates lifts Operates prime piler to stack sheets Removes prime and reject lifts	Manual using levers and buttons	5
Weighing	Weigher	Conveyors Scales	Operates print-weigh scales Records	Push-button control with visual monitoring	5

(concluded)

Operation	Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Load coil to mandrel	Coil Feeder	Coil conveyor Coil shunter mandrels Pinch Rolls and Loop Guide Trimmer	Refer to production order. Positions coil on mandrel. Guides coil between rollers, through trimmer, to shear. Sets and adjusts trimmer.	Manually actuated using electric power; push buttons used with direct visual control; some manipulation of strip	5
Strip Trimming	Scrap Baller	Scrap Baller	Inserts scrap end into baller. Starts and stops baller. Expels scrap from baller.	Hand tool(hook) used to effect insertion. Push buttons for activating and stopping baller.	2,5
Shear and Level	Shearman	Flying shear Leveller	Sets flying shear for desired length. Stops and starts shearing line. Sets and Resets leveller	Manual adjustment of shear, push button actuation; manual setting of leveller.	2,5
Inspect and separate into piles ("Assorting")	Assorter	Conveyor Reject piler Stenciller	Inspects sheets for defects. Signals end of lift by reference to production order and mechanical counter. Operates reject piler and records defects. Changes stencil.	Direct visual inspection; push buttons to operate pilers; manual changing of stencils.	5

(continued)

D3: SHEAR LINE (Prior to Hot Dip Tinning)

Operation	Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Pile	Mechanical Piler	Separator Blocks Prime Piler Roller Conveyors	Separates lifts. Operates prime piler to stock sheets. Removes completed prime lifts. Removes lifts of rejects.	Manual insertion of blocks; levers and push buttons to operate pilers and move lifts to conveyors.	5
Weighing	Weigher	Conveyor Scales	Operates Print-weigh scale Records product information	Push-button control with visual monitoring.	5
Transport to Hot Dip Tinning Line	Tractor Operator	Tractor	Transports lifts to Hot Dip Tinning Line.	Tractor driving	4

(concluded)

D3: SHEAR LINE (Prior to Hot Dip Tinning)

Operation	Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Load and Feed Sheets	Tin Pot Feeder + Repairmen	Skids Conveyor	Refers to production ticket. Transfers lifts to automatic feeding equipment and positions. Monitors functioning of equipment and makes adjustments.	Manual shunting of skids holding stacked sheets onto conveyor. Automatic actuation and operation of conveyor mechanism.	1,8
Pickling	Tin Pot Feeder + Tin Coating Equipment Operator + Repairmen	Conveyor Electrolytic Pickler	Checks solution in pickling tank. Makes additions to solution. Makes adjustments to equipment.	Visual checking; additions made by operating valves.	5
Tinning	Tin Pot Feeder + Tin Coating Equipment Operator + Repairmen	Guides Rollers Tin Pot Tinning Machine (conveyor)	Adds pigs of metal to pot. Adds and skims flux. Monitors temperature of metal and palm oil and makes adjustment. Monitors functioning of equipment.	Tongs used to make additions, ladles for skimming flux.	2,5
Washing	Tin Pot Feeder	Wet Washer (automatically replenished and drained)	Monitors level of solution.	Visual, valve operation	1,2
Apply oil to Surface	Tin Pot Feeder + Repairmen	oiler and branner (automatic)	Replenishes Bran.	Automatic operation, manually replenished.	2,5

(continued)

D3: HOT DIP TINNING

Operation	Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Inspect and Classify	Assorter	Conveyor Sheet counter	Visually inspects and sorts sheets. Diverts sheets to reject and prime piles. Spaces sheets.	Direct inspection, push-button operation of conveyor.	1,5
Pile	Tin Pot Feeder	Piler (automatic)	Checks and straightens Piles.	Manual	1,5

(concluded)

Operation	Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Load coil to uncoiler	Feeder	Uncoiler (Mandrels) Slitter	Refers to production sheets. Positions coil on mandrel. Trims scrap from coil. Starts coil end in slitter.	Positioning manually actuated using electric power; hand tool used to trim scrap end.	2,5
Slitting (Trimming edges to achieve desired width)	Slitter and Scrap Baller	Slitter (Continuous running) Scrap baller	Sets desired width and starts up, monitors for correct width. Adjusts reel tensions, loop control, welding temperature, guides, burr masher. Inserts scrap end into baller. Starts and stops baller. Expels scrap from baller.	Visual monitoring, regulation by push button action for settings and adjustments; hand tool (hook) used for insertion. Baller actuated manually, operated by electric power.	5
Weld coils end to end	Feeder	Lap welder	Squares and lap welds coil ends together. Removes scrap and reject material.	Manually actuated using electric power.	5
Recoil	Slitter	Coiler	Recoils and removes coils. Inspects quality and rejects defective material.	As for welding; visual inspection.	5
Weigh	Stocker	Scale	Weighs coils. Records coil information.	Push button control with visual monitoring.	5
Transport to Electrolytic Tinning line	Process Craneman	Crane "C" hook	Moves coil to Electrolytic Tinning line.	Direct vision, manipulation of levers.	4

D4: COIL PREPARATION (Prior to Electrolytic Tinning)

Operation	Operator(s)	Equipment Used	Method	Mode of Control	Level of MecHanization (J.R. Bright scale)
Load coils to coiler and weld ends together.	Electrolytic Feeder	Uncoilers (2) End-squaring shear Lap welder (automatic)	Refers to production schedule. Positions coil on mandrel. Starts free end through rollers. Cropsoff scrap end of coil and removes. Lap welds coil ends together. Adjusts welder temperature.	Manually actuated using electric power; visually guided and some direct manipulation.	1,5
Alkaline cleaning and rinsing.	Solution Tender	(Continuous flow) Tanks, gauges Cleaner	Refers to test reports. Checks solution levels and temperatures. Makes necessary additions and adjustments.	Uses lab reports and instrument readings to make manual adjustments.	9
Electrolytic deposition of tin.	Electrolytic Tinning Operator	(Continuous flow) Plating tanks Rolls Automatic controls	Refers to test reports. Adjusts plating efficiency. Adjusts tensions, speeds, currents. Examines quality of strip.	as above	12
Melting (to give even distribution and adhesion)	Electrolytic Tinning Operator	(Continuous flow) Melting unit	as above	as above	12
Marking	Electrolytic Tinning Operator	Printing rolls	Checks stencils. Replenishes ink.	Manual	5

(continued)

D 4: ELECTROLYTIC TINNING LINE

Operation	Operator(s)	Equipment Used	Method	Mode of Control	Level of Mechanization (J.R. Bright scale)
Chemical treatment and oiling	Electrolytic Tinning Operator	(Continuous flow) Chemical treatment Tanks and equipment Oilers	Makes necessary addition to chemical solution. Adjusts current. Adjusts oiler.	Manual	6
Recoiling	Coiler	Coilers, shear Pinch rolls	Adjusts line speed, pinch rolls, shear tension. Start, recoil, remove coils.	(as for loading coil)	6
Weighing	Stocker	Weighing machine	Weighs coils. Records coil information.	Push button control Visual monitoring	5
Transporting coil to shear line	Tractor operator	Tractor	Move coil to shear line.	Tractor driving	4

D 4: ELECTROLYTIC TINNING LINE (concluded)

D4: SHEARLINE (after Electrolytic Tinning) as for D3 (Hot Dip Tinning Shearline) with strip-trimming omitted.

3. CHARACTERISTICS OF TOTAL PRODUCT MIX AND OF PRODUCT SELECTED

To ensure comparability of the manhour/skill inputs between the two technologies, it was necessary to select from their respective product mixes one that was as nearly identical as possible. It would have been desirable for each product selected to conform to a second criterion, i.e., that it should be chosen from amongst those most frequently manufactured. This criterion could not always be met.

The tables in this section show the extent to which the products selected depart from the typical product of each technology along several critical dimensions.

TABLE III-1

C3, SHEET GALVANIZING

	Product or Process Variables			
	Gauge	Width	Length	Speed of Line
Full range for all products	8 - 19	24" - 49"	71 - 171	11.5 - 38.5 ft/min.
Range for most frequent product types	8 - 11	34" - 38"	96 - 130	15.5 - 18.5 ft/min.
Product selected	14	36"	120	26.5 ft/min. average

TABLE III-2

C4, CONTINUOUS GALVANIZING

	Product or Process Variables		
	Gauge	Width	Speed of Line
Full range for all products	10 - 28	21" - 54"	93 - 300 ft/min.
Range for most frequent product types	12 - 20 (0.036 - .0406)	33" - 39"	235 - 300 ft/min.
Product selected	14 (.0734 - .0846)	36"	133 ft/min.

TABLE III-3

D3, HOT DIP TINNING

	Product or Process Variables			
	Coating weights lb.per base box	Widths	Lengths	Speeds of Line
Full range for all products	1.10, 1.35, 1.60	18 - 34	20 - 36	35 ft/min.
Range for most frequent product types	1.10	28 - 32	30	35 ft/min.
Product selected	1.10	34	34	35 ft/min.

TABLE III-4

D4, CONTINUOUS ELECTROLYTIC TINNING

	Product or Process Variables		
	Coating weights lb.per base box	Widths	Speeds of Line
Full range for all products	.10 - 1.00	24 - 36	594 ft/min-1250 ft/min.
Range for most frequent product types	.25 - ..75	34	900 - 1250 ft/min.
Product selected	1.00	34	594 ft/min.

4. RAW DATA USED FOR THE DEVELOPMENT OF SKILL PROFILES

These data are tabulated under the title of each process, with the volume of product processed per shift in parentheses. The following notes explain the meaning of each column in the tables:

Job Code:	The codes are internal codes, assigned to each job to facilitate cross-referencing. The letter identifies the firm, the attached figure identifies technology and the figure separated by a dash, the job.
Job D.O.T. No.:	These six digit numbers are taken from the 1965 edition of the Dictionary of Occupational Titles. The matching of D.O.T. number and job was done by the researchers on the basis of job description and their own knowledge of the jobs.
Job Title:	Official titles assigned to the jobs by the firm.
Skill Level:	Total skill factor points derived from the job evaluation scheme operative throughout the steel industry.
Manhours:	Determined from crew requirements established by the firm and from discussions with personnel familiar with the operations.
Volumes:	Determined by reference to operating specifications and product dimensions (e.g., speed, firing time, width of product, etc.) and checked with the firms' Industrial Engineering personnel.

FIRM C: GALVANIZING

C3 SHEET GALVANIZING

Shear Line (Volume: 292 Tons per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift
C3-1	892.883	Hooker	1.0	5.3
C3-3	509.886	Wrapper	1.0	4
C3-4	509.886	Sheet Piler	1.9	8
C3-7	224.487	Weigher	2.7	8
C3-8	929.883	Tractor Operator-Ross Carrier	2.8	12
C3-9	921.280	Galvanizing Craneman	2.8	2.7
C3-10	613.885 613.782	Coil Feeder	2.9	8
C3-12	615.782	Flying Shearman	4.2	8
C3-13	703.887	Assorter	4.2	8
C3-15	619.381	Sheet Inspector	4.2	0.8

Sheet Galvanizing Line (Volume: 68.4 tons per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift
C3-1	892.883	Hooker	1.0	8
C3-2	703.887	Assorter Helper	1.5	16
C3-5	509.886	Sheet Feeder	1.9	8
C3-6	501.885 703.887	Spellhand	1.9	8
C3-7	224.487	Weigher	2.7	8
C3-9	921.280	Galvanizing Craneman	2.8	8
C3-11	703.887	Assorter	2.9	8
C3-14	501.885	Potman	4.2	8

C4 CONTINUOUS GALVANIZING (Volume: 204.1 tons per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift
C4-1	892.883	Hooker Helper	1.0	2
C4-2	509.886	Sheet Piler	1.9	8
C4-3	224.487	Weigher	2.7	8
C4-4	892.883 929.883	Stocker	2.8	8
C4-5	921.280	Galvanizing Craneman	2.8	9
C4-6	626.884 703.887	Assorter	2.9	8
C4-7	613.885 613.782	Coil Feeder	4.2	8
C4-8	613.782	Continuous Galvanizer Shearman	4.2	8
C4-9	619.381	Sheet Inspector	4.2	4
C4-10	503.885	Assistant Continuous Galvanizer Operator	4.6	8
C4-11	503.885	Continuous Galvanizer Operator	6.3	8

FIRM D: TINNING

D3 HOT DIP TINNING

Shear Line (Volume: 3,380 Base Boxes per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift
D3-1	509.885	Scrap Baller	0	8
D3-2	224.487	Weigher	1.5	8
D3-3	613.885	Feeder	1.9	8
D3-4	509.886	Mechanical Piler	1.9	8
D3-5	703.887	Assorter Shear Line	2.5	8
D3-7	929.883	Tractor Operator-Tractor Weigher	2.8	1.5
D3-10	615.782	Shearman	4.2	8
D3-11	619.380	Product Inspector	4.6	4

Hot Dip Tinning Line (Volume*: 183.1 - 1281.7 Base Boxes per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift	Base Boxes* Per Shift
D3-6	703.887	Assorter-Tinning Machine	2.5	8	183.1
D3-7	929.883	Tractor Operator-Tractor Weigher	2.8	1.5	1281.7
D3-8	553.782	Tin Pot Feeder	2.8	8	549.3
D3-9	929.883	Tractor Operator	2.8	8	1281.7
D3-12	619.380	Tin Pot Equipment Repairman	5.4	8	732.4
D3-13	501.885	Tin Coating Equipment Operator	5.8	8	732.4
D3-14	619.380	Hot Dip Tin Equipment Repairman	5.8	8	1281.7

*Within a certain range of Base Boxes per shift produced there are no commensurate reductions in manhours because operators are assigned for a range of Tinning Lines in operation. For example, one Tin Coating Equipment Operator (D3-13) is required whether only 1 or as many as 4 Tinning Lines are operating. The volumes shown for each job reflect the maximum number of furnaces operating for the corresponding manhours.

D4 ELECTROLYTIC TINNING

Coil Preparation Line (Volume: 10,500 Base Boxes per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift
D4-1	509.885	Scrap Baller	0	8
D4-2	613.885	Feeder-Coil Preparation Line	1.9	8
D4-5	{829.883 224.487}	Stocker	2.3	2
D4-13	615.782	Slitter	4.2	8
D4-15	619.380	Product Inspector	4.6	4

Electrolytic Tinning Line (Volume: 3,186 Base Boxes per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift
D4-5	{829.883 224.487}	Stocker	2.3	2
D4-8	511.782	Solution Tender	2.8	8
D4-9	929.883	Tractor Operator	2.8	4
D4-10	613.782	Electrolytic Feeder	2.9	8
D4-11	921.280	Process Craneman	3.2	2
D4-12	613.885	Coiler	4.1	8
D4-15	619.380	Product Inspector	4.6	4
D4-16	501.130	Electrolytic Tinning Operator	5.7	8

Shear Line (Volume: 3,380 Base Boxes per shift)

Job Code	Job D.O.T. No.	Job Title	Skill Level	Manhours Per Shift
D4-3	613.885	Feeder-Shear Line	1.9	8
D4-4	509.886	Mechanical Piler	1.9	8
D4-6	703.887	Assorter-Shear Line	2.5	8
D4-7	929.883	Tractor Operator-Tractor Weigher	2.8	3
D4-14	615.782	Shearman	4.2	8
D4-15	619.380	Product Inspector	4.6	4

5. LENGTH OF OPERATORS' GENERAL EDUCATION AND ON-THE-JOB EXPERIENCE

The internal job codes and job titles used in Section 5 are retained to facilitate cross-referencing.

Estimates of general educational requirements made by researchers.

Estimates of on-the-job experience requirements supplied by the firms.

FIRM C: GALVANIZING

Job Code	Job Title	Estimated Required General Education (Years of High School) 0	1-2	3-4	On-the-job Experience (Months) 0-2	3-6	7-12	13-18	19-24	25-30
C3	SHEET GALVANIZING									
	Shear Line (Volume: 292 tons/shift)									
C3-1	Hooker	X			X					
C3-2	Wrapper	X				X				
C3-3	Sheet Piler	X				X				
C3-4	Sheet Piler	X					X			
C3-7	Weigher	X				X				
C3-9	Galvanizing Craneman	X				X				
C3-10	Coil Feeder	X					X			
C3-12	Flying Shearman		X					X		
C3-13	Assorter	X					X			
C3-15	Sheet Inspector		X					X		
	Sheet Galvanizing Line (Volume: 68.4 tons/shift)									
C3-1	Hooker	X			X					
C3-2	Assorter Helper	X			X					
C3-5	Sheet Feeder	X				X				
C3-6	Spellhand	X				X				
C3-7	Weigher	X					X			
C3-9	Galvanizing Craneman	X				X				
C3-11	Assorter	X					X			
C3-14	Potman		X					X		
C4	CONTINUOUS GALVANIZING (Volume 204.1 tons/shift)									
C4-1	Hooker Helper	X			X					
C4-2	Sheet Piler	X				X				
C4-3	Weigher	X					X			
C4-4	Stocker	X				X				
C4-5	Galvanizing Craneman	X				X				
C4-6	Assorter	X					X			
C4-7	Coil Feeder	X						X		
C4-8	Continuous Galvanizer Shearman		X					X		
C4-9	Sheet Inspector		X					X		
C4-10	Assistant Continuous Galvanizer Operator		X						X	
C4-11	Continuous Galvanizer Operator			X						X

FIRM D: TINNING

Job Code	Job Title	Estimated Required General Education (Years of High School)			On-the-job Experience (Months)					
		0	1-2	3-4	0-2	3-6	7-12	13-18	19-24	25-30
D3 HOT DIP TINNING										
Shear Line (Volume: 3,380 Base Boxes/shift)										
D3-1	Scrap Baller	X			X					
D3-2	Weigher	X			X					
D3-3	Feeder	X				X				
D3-4	Mechanical Piler	X				X				
D3-5	Assorter Shear Line	X				X				
D3-7	Tractor Operator - Tractor Weigher	X				X				
D3-10	Shearman		X					X		
D3-11	Product Inspector		X						X	
Hot Dip Tinning Line (Volume: 183.1 - 1,281.7 Base Boxes/shift)										
D3-6	Assorter - Tinning Machine	X				X				
D3-7	Tractor Operator -Tractor Weigher	X				X				
D3-8	Tin Pot Feeder	X				X				
D3-9	Tractor Operator	X				X				
D3-12	Tin Pot Equipment Repairman	X					X			
D3-13	Tin Coating Equipment Operator		X						X	
D3-14	Hot Dip Tin Equipment Repairman	X							X	
D4 ELECTROLYTIC TINNING										
Coil Preparation Line (Volume: 10,500 Base Boxes/shift)										
D4-1	Scrap Baller	X			X					
D4-2	Feeder - Coil Preparation Line	X				X				
D4-5	Stocker	X				X				
D4-13	Slitter	X						X		
D4-15	Product Inspector		X						X	
Electrolytic Tinning Line (Volume: 3,186 Base Boxes/shift)										
D4-5	Stocker	X				X				
D4-8	Solution Tender	X				X				
D4-9	Tractor Operator	X				X				
D4-10	Electrolytic Feeder	X					X			
D4-11	Process Craneman	X					X			
D4-12	Coiler	X						X		
D4-15	Product Inspector		X						X	
D4-16	Electrolytic Tinning Operator			X						X
Shear Line (Volume: 3,380 Base Boxes/shift)										
D4-3	Feeder - Shear Line	X			X					
D4-4	Mechanical Piler	X				X				
D4-6	Assorter - Shear Line	X				X				
D4-7	Tractor Operator - Tractor Weigher	X				X				
D4-14	Shearman		X					X		
D4-15	Product Inspector		X						X	

6. ANALYSIS OF VARIANCE LAYOUT OF DATA AND DETAILED SUMMARY

Improved estimate of residual variance was obtained by pooling the sums of squares and the degrees of freedom of the original residual estimate and of the T x F interaction.

The mean squares of the SL x T and SL x F interactions and of the main effects were tested against this improved estimate.

Key to abbreviations:

D.F. - Degrees of freedom

S.S. - Sums of squares

M.S. - Mean squares

V.R. - Variance ratio

SL - Skill levels

T - Technology levels

F - Firms

TABLE III-5

Manhours per unit product classified by
skill level, firm and technology

Skill Level	Technology 1		Technology 2	
	Firm 1 (C3)	Firm 2 (D3)	Firm 1 (C4)	Firm 2 (D4)
Low	1.35	0.24	0.10	0.08
Medium	9.65	7.56	2.01	1.65
High	1.74	3.17	1.76	1.09
Totals	12.74	10.97	3.87	2.82

TABLE III-6

Analysis of Variance Summary

Source of Variance	D.F.	S.S.	M.S.	V.R.	Significance Level
Between skill levels	2	47.72	23.86	33.1	P 0.01
Between technologies	1	24.14	24.14	33.5	P 0.025
Between firms	1	0.67	0.67	0.9	
SL x T	2	23.32	11.66	16.2	P 0.025
SL x F	2	1.29	0.65	0.9	
T x F	1	0.04	0.04	0.0	
Residual	2	2.11	1.06		
Improved residual estimate	(3)	(2.15)	(0.72)		
Total	11	99.29			

7. JOB DESCRIPTIONS

C3-1 - Hooker 1.0

Signals and hooks for crane man in transporting hot rolled and cold reduced sheets from storage to sheet galvanizing storage and to the entry end of the galvanizing line, and finished sheets from the exit end of the galvanizing line to storage.

C3-2 - Assorter Helper 1.5

Assists catcher to turn over, inspect, stencil, sort and pile sheets at exit end of galvanizing line.

C3-3 - Wrapper 1.0

Checks loading plan prepared by checker to determine lifts and type of paper wrapping required in individual shipping piles. Paper wraps and/ or bands lifts of sheets and coils for shipping. Stencils or marks required identification on lift.

C3-4 - Sheet Piler 1.9

Operates prime and reject pilers on shear line. Inspects sheets after leveling for flatness. Assists in removing cobbles. When oiling machine is in line, observes its operation and regulates oil flow to maintain proper coating on sheets. Removes and piles separator blocks and rails from return conveyor.

C3-5 - Sheet Feeder 1.9

Manually feeds pickled hot rolled and cold reduced sheets and unpickled cold reduced sheets into the rolls of the galvanizing machine. When relieving potman, controls line speed and makes other routine adjustments and adds zinc, antimony, or flux as necessary. Assists in drossing operations.

C3-6 - Spell Hand 1.9

Relieves feeder, catcher, and catcher helper and performs a variety of ancillary, transporting, preparatory, and cleaning duties.

C3-7 - Weigher 2.7

Weighs lifts of sheets on scales at delivery end of shear lines. Prepares lift and shipping tickets, and calculates and posts theoretical sheet weight for each lift. On production report posts order number, gauge, size, type of shearing, coil number, width, weight of incoming material, number of sheets produced, ticket number, theoretical and actual weights, and operation change codes. Recaps defects and their causes. Performs such other duties as the taking of inprocess and warehouse inventories.

C3-8 - Tractor Operator - Ross Carrier 2.8

Operates a Ross carrier to transport material in the sheet finishing department as required.

C3-9 - Galvanizing Craneman 2.8

Operates electric overhead crane to service the following areas: sheet galvanizing line, recovery pot, continuous coating line roll pond, transfer conveyor, and pickling vats. Makes miscellaneous lifts in storage and maintenance areas. Regularly lubricates crane and inspects cables and brakes. Checks limit switches.

C3-10 - Coil Feeder 2.9

Operates uncoiler and feeds coils on shear line. Checks coil numbers on production schedule as coils are charged and notifies shear man of deviation from scheduled sequence. Assists in threading strip through side trimmer. Removes or assists in removal of cobbles from shear line.

C3-11 - Assorter 2.9

Inspects, stencils, piles, and assorts sheet product at exit end of galvanizing line.

C3-12 - Flying Shear Man 4.2

Directs flying shear crew and operates line in shearing hot rolled coils into sheets. Sets guides and side trimmer knives, clearance of side trimmer knives for gauge of strip, and guillotine-type shear. Adjusts shear and roller levelers. Checks random sheets for size, gauge, and squareness. Synchronizes line units to form proper loops.

C3-13 - Assorter 4.2

Prepares stenciling equipment with proper identification information. Inspects each sheet for flatness and surface defects. Assists shear man in measuring and gauging sheets. Removes and piles rails and separator blocks from return conveyor to reject piler. Records numbers and type of rejects on assorter's reject analysis report. Assists in removing cobbles from line.

C3-14 - Pot Man 4.2

Is responsible for the operation of the hot dip galvanizing pot to obtain acceptable quality of appearance, flatness, tightness and weight of coating. Adjusts pot temperature, and rheostats controlling pot speeds and roller leveler speeds. Adds zinc or antimony pigs to raise level of molten metal as necessary. Makes weight of coating tests occasionally. Makes regular additions to flux of salammoniac and tallow. Dresses pots, adds hydrochloric acid to feed tank, directs crane in pulling out and replacing pot rigging and exit rolls.

C3-15 - Sheet Inspector 4.2

Makes random inspection tours throughout the turn of each of the sheet finishing units inspecting a representative amount of each order processed to ensure conformity with inspection standards. The sheet finishing units inspected include: sheet temper mill, hot rolled and cold reduced shear lines, levelers, forming, coating, resquare, and scrubber. Notifies operating personnel immediately of any material being processed containing defects that will cause excessive rejections in subsequent operation. Advises operating personnel on classification and disposition of defects with which operating crew is not familiar. Assists supervisors in developing recommendations for corrective processing methods, treatments and practices. Assists in testing sheet products and collaborates with sheet mill metallurgist in inspecting sample and/or special orders. Prepares turn report covering all observations and inspections made. Assists in training assorters.

C4: Continuous Galvanizing

Each job title is preceded by the internal job code. The number to the far right is the skill factor point rating for the job.

C4-1 - Hooker Helper 1.0

Assists supply man (sheet and strip coating) in performing crane hooking at continuous coating and sheet galvanizing lines. Bands loads of supplies and by-products for transporting or storage. Stores tools and equipment in storage area provided.

C4-2 - Sheet Piler 1.9

Operates and adjusts prime piler and associated equipment and assists in operating reject piler at exit end of continuous coating line. Assists crew during roll changes, strip breaks, cobbles, etc.

C4-3 - Weigher 2.7

Weighs all types of galvanized sheet and coil product at the exit end of the continuous coating line. Weighs coils rejected and removed from the entry end of the continuous coating lines. Calculates actual weight per sheet of product produced and checks it against the theoretical weight per sheet. Posts data on production report, such as order number, description, number of sheets, weight, load number, shipping instructions, etc. Performs such other duties as taking inventories.

C4-4 - Stocker 2.8

Stocks, records location and crane hooks incoming coils for use on the continuous coating lines. Operates tractor to transport supplies and by-products to and from continuous coating and sheet galvanizing lines. Crane hooks lifts from exit end of continuous coating line and lifts of galvanized sheets to and from cross-conveyor. Records on chemical and metal transfer reports amounts of sheet and strip coating supplies and by-product moved. Occasionally operates overhead traveling crane as required in servicing the zinc pot.

C4-5 - Job title and job description identical with job code C3-9. 2.8

C4-6 - Assorter 2.9

Assorts sheets in absence of shear man. Sets up stenciling equipment and assists shear man and sheet piler in miscellaneous work at delivery section of continuous coating line. Assists tractor operator in preparing coils and applying bands. Assists pot man in placing wipes for wiped product. Assists in making minor repairs and adjustments to finishing end equipment, rethreading line, clearing cobbles, obtaining samples, etc.

C4-7 - Coil Feeder 4.2

Operates uncoilers, welder and cleaning equipment at the entry end of the continuous coating line. Inspects incoming coils for obvious defects. Rejects coils as directed by the operator. Removes defective outside wraps of coils using hand shears, unishear, or torch. Operates tractor in case of emergencies, or signals crane in positioning coils on ramp or removing defective coils.. Assists crew during roll changes, strip breaks, and cobbles. Rewelds incoming spot welds as required.

C4-8 - Continuous Galvanizer Shear Man 4.2

Operates shear, leveler, conveyors, and pilers or recoilers at the exit end of continuous coating line. Inspects and assorts all material produced for surface and shape defects. Removes sheets with welds, shape or coating defects. Shears out defective coil sections and provides metallurgical samples. Assists crew during all changes, strip breaks and cobbles.

C4-9 - Sheet Inspector 4.2

Same as for job C3-15.

C4-10 - Assistant Continuous Galvanizer Operator 4.6

Inspects coated strip and notifies operator of defective cleaning or annealing or regulates temperatures, drives, alignment, gas-torches, and metal level in coating unit to correct coating defects. Prepares coating rolls for replacement in coating unit. Loads and operates the pig conveyor for the pre-melt furnace. Regulates temperature and metal level in pre-melt furnace and roll coating pond. Assists in repairing all strip breaks and in the removal of all by-products and used equipment for coating area. Periodically inspects solution basement and adjusts valves and pumps as directed by operator. Prepares a report of spelter usage.

C4-11 - Continuous Galvanizer Operator 6.3

Determines that production schedule is in accordance with established proper practices of line operation. Prepares report of line operation. Observes checks and controls or directs control of all components of the line to achieve proper operating conditions. Inspects condition of coating and associated equipment and assists the assistant operator in cleaning adjustment and repairs. Interprets and analyzes chemical and physical reports from lab. Makes proper adjustments to equipment and makes or directs additions to process materials such as gasses, alloys, chemicals, etc. Inspects finished product for quality. Occasionally inspects operating conditions at dissociating unit. Directs and assists crew in changing rolls, repairing breaks, cobbles, operating furnace purging system in emergencies. Assists feeder in preparing and charging coils into line, and shear man and piler in changing sizes or removing finished product from the line. After weld is completed at entry end, follows it through line to exit end to avoid strip breaks.

D3: Hot-dip Tinning

Each job title is preceded by the internal job code. The number to the far right is the skill factor point rating for the job.

D3-1 - Scrap Baller 0.0

Operates scrap baller to ball side scrap from shear and dispose of line scrap.

D3-2 - Weigher 1.5

Reads automatic scales or occasionally operates balance scales to obtain weights of piles from shear and scrap. Prepares production and delay reports under direction of feeder from information supplied by stocker shear man and from own observations. Prepares re-treatment tickets as directed. Relieves feeder or piler at shear as required.

D3-3 - Feeder 1.9

Assists stocker in hooking and placing coils on cradle. Trims scrap from coils. Checks thickness and width of each coil for conformance to specifications. Places free end of coil in slitter and roller leveler. Observes incoming strip for defects, notifies shear man and takes corrective action. Checks side guides, off-weight gauge, and pin-hole detector for proper operation and makes necessary adjustments. Watches reject and mender pilers. Straightens skewed sheets and removes bent ones. Adjusts magnets to maintain proper shingle of sheets on conveyor. Inserts empty skids and removes completed lifts from reject piler. Prepares production and delay reports, lift tickets and treatment tickets. Works with crew in setting up and removing prime mender and salvage piles and removing cobbles.

D3-4 - Mechanical Piler 1.9

Operates piler to pile sheared coated and uncoated tin-plate. Operates controls to obtain specified number of sheets per bundle, to position piler hoist at proper level and to build up and remove prime piles. Examines sheets for shearing defects, roll marks, etc. Assists in the removal of cobbles and manually pushing piles from piler.

D3-5 - Assorter Shear Line 2.5

Examines sheets on moving classifier conveyor and diverts defective sheets. Checks sheets for flatness and defects. Hand assorts and counts check piles. Marks defective piles for hand-sorting.

D3-6 - Assorter Tinning Machine 2.5

Visually inspects and sorts plates and diverts prime plate to prime pile or unsatisfactory materials to menders and reject piles. Assists in checking for satisfactory piling with the aid of mirror over piler. Checks sheets periodically for gauge and shape. Spaces each sheet manually.

D3-7 - Tractor Operator - Weigher 2.8

Operates tractor to move and transport materials and supplies to and from the various operating units, stock room, warehouse, etc. Operates scale to obtain weights of piles from shear and scrap. Records electrolytic tin-plate sheared on production report including such data as order number, customer, size, weight of coating, amount produced, etc. Removes lift from conveyor and returns empty skids to shed. Checks accuracy of scale.

D3-8 - Tin Pot Feeder 2.8

Tends automatic feeding of plate through tin-pots for coating process. Maintains supply of bran in cleaning units of tin-pots and operates tractor to transport and position lifts of material and equipment. Cleans feeding equipment as instructed. Assists in re-assembling electrolytic pickling equipment, and in fighting pot fires in department.

D3-9 - Tractor Operator 2.8

Operates tractor to transport and position lifts of material and equipment.

D3-10 - Shear Man 4.2

Operates variable type controls to position, slit and shear coated or uncoated tin-plate to required size and squareness. Coordinates various units of line. Directs and assists in changing,setting up and adjusting slitter and shear knives, guides, and roller leveler. Directs setting up and removal of prime, salvage and mender piles. Is responsible for the quality of material sheared. Instructs tractor operator regarding supply of platforms. Checks shear line to be sure all parts are in place and functioning properly. Directs and assists crew in removing cobbles and in re-piling spilled lifts at shear.

D3-11 - Product Inspector 4.6

Inspects tin-mill products in all phases of production, such as hot rolled, pickled, cold reduced, cleaned and annealed strip, sheared uncoated plate, and electrolytic and hot dip tin-plate for surface defects, dimensions, shape, straightness, flatness, identification, etc. Notifies operating personnel when sub-standard material is being produced. Checks conformance to packaging and marking instructions. Interprets specifications for grade, tolerances, standards, etc.

D3-12 - Tin Pot Equipment Repairman 5.4

Inspects, adjusts, repairs, changes and realigns machinery on tin-pot production units. Assists unit operator to check plates for steel defects and corrects processing defects such as surface, burr edges, wavy edges, poor cleaning, shape, etc. Adjusts double detectors and feeding units. Helps maintain amount of flux. Watches temperature gauges and makes repairs on feeding and cleaning units on the lines. During dross turn helps to clean equipment after removal and inspects gears, chains, guides, rolls, etc. for defects and necessary repairs. Makes all chain and gear connections. Checks drop on tin machine and feeder and makes changes in gears and sprockets for speed differentials. Assists in fighting pot fires.

D3-13 - Tin Coating Equipment Operator 5.8

Directs, regulates, and controls the operation of two to four hot-dip tinning lines and auxiliary equipment. Analyzes coating weight reports and adjusts tinning machines as required to secure proper amount and speed of coating. Adjusts metal and oil temperature. Directs and assists crew in making equipment repairs and in changing equipment and making additions of pig tin to tin-pot. Adjusts speed of line units, adds inhibitor to pickling units, selects random sample of coated plate for coating determination by laboratory. Assists in fighting pot fires in department and records information on delay forms.

D3-14 - Hot Dip Tin Equipment Repairman 5.8

Rebuilds, repairs, replaces, and adjusts tinning, cleaning, and automatic feeding equipment on hot dip units. Assists in tending operation of pots, in fighting pot fires in department and in checking plates for steel defects. Skins pots as directed and removes cobbles from units. During dross turn, helps to clean equipment after removal, assists in putting feeding and tinning equipment back into pot. Makes all chain and gear connections. Changes gears and sprockets. Checks drop on tin machine and feeder. Operates tractor to haul lifts of plate, supplies, etc.

D4: Continuous Electrolytic Tinning

Each job title is preceded by the internal job code. The number to the far right is the skill factor point rating for the job.

D4-1 - Scrap Baller 0.0

Operates scrap baller to ball side scrap from slitter and dispose of line scrap. Signals and hooks for crane man to dispose of scrap.

D4-2 - Feeder - Coil Preparation Line 1.9

Feeds strip into coil preparation line and disposes of reject material. Observes quality of incoming strip and advises slitter man of defects. Signals slitter man to slow down for end of coil, bad sections, welds, etc. Inserts marker to identify welds or defects in coil. Checks thickness and width of coils. Prepares production and delay reports. Also prepares coil tickets and re-treatment tickets.

D4-3 - Feeder - Shear Line 1.9

Feeds coated and uncoated tin-plate strip in and through shear line. Removes spent coil ends and scrap from uncoiler. Prepares production and delay reports. Prepares lift tickets and re-treatment tickets. Works with shear man in changing, setting up, and adjusting slitter and shear knives, adjusting roller leveler, and checking for flatness, polishing, and cleaning leveler rolls, etc. Works with crew in setting up and removing prime mender and salvage piles and removing cobbles. Assists in re-piling cobbled piles or spilled lifts at shear.

D4-4 - Mechanical Piler 1.9

Operates piler to pile sheared, coated and uncoated tin-plate. Operates counter control to obtain specified number of sheets per bundle. Assists shear man with salvage and mender pilers and adjusts classifier for proper operation. Examines sheets for shearing defects, roll marks, etc. Assists with shear knife changes and in removal of cobbles.

D4-5 - Stocker 2.3

Stocks shear line, coil preparation line, and electrolytic line in accordance with operating schedules, and weighs production from temper mill and coil preparation line. Receives order tickets. Completes necessary information such as size, weight, width, etc. and inserts them in proper coils. Marks weight and size information on coils. Maintains physical inventory of stock.

D4-6 - Assorter - Shear Line 2.5

Examines sheets from moving classifier conveyor and diverts defective sheets. Checks for flatness and defects. Hand sorts and counts check piles. Marks defective piles for handsorting.

D4-7 - Tractor Operator - Weigher 2.8

As for job D3-7.

D4-8 - Solution Tender 2.8

Checks solution levels and temperatures, pile levels, sprays, etc. and makes necessary additions and adjustments. Checks and gauges all anodes in plater and moves anodes as required to maintain proper spacing between anodes and strip. Operates and cleans evaporator. Checks all solution systems, tank pumps, heaters, packing glands, etc. for leaks and sees that all related equipment is operating properly. Directs and assists laborers and crew in removing and disposing of sludge from all tanks, in steaming and washing down of equipment; relieves coiler operator, feeder and tractor operator when necessary.

D4-9 - Tractor Operator 2.8

Operates tractor to remove coils from electrolytic tinning line carriages to storage area, to shear lines, or to up-ender; and to haul supplies and materials. Operates scales to obtain necessary weights and records them. Assists electrolytic crews in removing cobbles and broken strip, rethreading lines, placing scrap in containers, clean-up, removing and replacing anodes, and on shutdowns and start-ups.

D4-10 - Electrolytic Feeder 2.9

Operates controls to prepare and feed coils, alter line speeds and tensions, crop off scrap-end of coil, and lap-weld on free end of new coil. Observes incoming strip for shape, surface defects and welds; and checks thickness and width of every coil. Signals crane man by standard hand signals to hook coils from floor and place them on cradle. Changes heat setting on welder transformer to assure proper weld. Makes guide changes for strip width. Removes and disposes of spent coil ends, scrap and off-gauge material, and records. Maintains record of material charged by size, weight, coil, etc. Assists in changing shear knives and participates in removal of cobbles and repairing broken strips.

D4-11 - Process Crane Man 3.2

Operates electric overhead traveling crane to transport material and equipment in and between temper mills, black plate shear, coil preparation lines, and electrolytic tinning lines. Operates crane for maintenance crews while repairing and replacing equipment.

D4-12 - Coiler 4.1

Operates variable controls to decelerate line speed, lower pinch roll, start winding reel and belt wrapper, shear strip, remove belt wrapper, adjust tension, release pinch roll, and accelerate line speeds and remove coils. Adjusts air and voltage for proper cottonseed oil film at electrostatic oiler. Posts coil weights as per chart to production reports and keeps necessary records. Checks strip for quality and makes corrections to eliminate defects when possible. Works with crew in removing damaged strip, repairing broken strip, and changing double-cut and snip shear knives.

D4-13 - Slitter 4.2

Operates variable type controls to slit and recoil uncoated tin strip to required width, to remove prime and reject coils from coilers and to start new coils. Operates rheostats for proper line and reel tension, loop control, etc. to coordinate various units of the line. Watches thickness gauge and observes steel quality to determine what part of strip should be rejected and cuts out defective material. Directs feeder in disposing of reject material and squaring and lap-welding coil ends. Adjusts heat setting on welder transformer to assure proper weld. Examines incoming strip for defects and makes necessary corrections.

D4-14 - Shear Man 4.2

Operates variable type controls to position, slit, and shear coated or uncoated tin-plate to required size and squareness. Adjusts rheostats for proper reel control and belt speeds, etc. to coordinate various units of the line. Directs and assists in changing, setting up, and adjusting slitter and shear knives, guides, etc. to cut strip to required size and squareness and in adjusting roller leveler to level sheets to required flatness. Directs setting up and removal of prime salvage and mender piles. Is responsible for quality of material sheared. Instructs tractor operator regarding supply of platforms. Directs and assists crew in removing cobbles and assists in repiling spilled lifts at shear.

D4-15 - Product Inspector 4.6

Same as for job D3-11.

D4-16 - Electrolytic Tinning Operator 5.7

Directs and works with crew in the set up, operation, and adjustment of the electrolytic tinning line. Adjusts rheostats to coordinate various units of the line. Determines and adjusts current and cleaner and pickler and other auxiliary equipment and makes periodic changes of current to assure clean strip for plating and pickling, cleaning, re-flowing, and chemical treatment and oiling. Makes necessary adjustments to plater current control for changes in plating efficiency and makes or corrects chemical additions to cleaning, pickling, plating, and chemical treat solutions. Checks oiling on strip and adjusts oiler. Periodically checks performance of pin-hole detector. Examines strip for signs of dirty rolls, pick-up or other defects, such as in coating or from previous operations and takes or directs corrective action or recommends that strip be re-treated. Recommends roll changes or mechanical repairs. Directs crew in removing cobbles and repairing broken strip. Maintains record of operating delays and conditions. Operates or directs operation of evaporator.

APPENDIX IV

AEROSPACE

Conventional and Numerically Controlled
Machining of Complex Parts

APPENDIX IV

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1. OUTLINE OF TECHNOLOGIES

For some time past the aircraft and aerospace industries have been the largest users of numerically controlled machine tools amongst the six major industries employing these tools. Many aspects of the key technological advance constituted by tape-actuated tools, especially in its bearing on problems of employment, skill and training have recently been discussed in considerable detail in a study published by the Bureau of Labor Statistics.*

The older technology is here represented by conventional machine tools, (lathes, milling machines, drills, etc.) (studies E1, F1) used for the machining of individual components in small series. They date back to the early Industrial Revolution and their invention gave rise to the metal working industries; they are also widely found in maintenance workshops in virtually every manufacturing industry. The history of machine tools is one of uninterrupted development aimed at achieving greater and greater uniformity in the parts produced: towards this end more and more of the guiding and controlling functions had to be taken out of the hands of the operator and built into the tool. Nevertheless even in the most advanced versions of shapers, grinders, milling machines, lathes etc. the machine tool operator is still closely involved at every stage of the process. In particular he:

(i) plans the operations: - This includes determining the proper tools to be used, the best sequence, the number of cuts to be made, the appropriate speed, feed and depth of each cut and the method for setting up the machine.

(ii) makes part layout and reference layout: - from blueprints, templates and sketches, he lays out contours on the workpiece and inscribes reference lines and guidepoints.

(iii) sets up and loads the machine: - Included are the locating of auxiliary machine attachments, fixtures, cutting tools and parts, and the orienting and positioning of the workpiece in relation to the cutting tool.

(iv) controls the operation: - Referring frequently to the blueprint, the operator carries out frequent checks and measurements on dimensions, each cutting step being a closer approximation to the final shape. Resetting of the components and readjustment of the speeds and feeds is also necessary at intervals, depending in part on the operator's skill.

In one of the two firms, tracer machine tools are used fairly extensively and in a sense this technology can be regarded as being intermediate between conventional and N/C machining. The tracer attachments which constitute the distinguishing feature of these tools are capable of following the contours of a specially prepared template, and this both speeds up and makes more accurate such operations as profiling or drilling at prescribed points.

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* Ref. B.L.S. report, "Outlook for Numerical Control of Machine Tools", Bulletin #1437, Washington, D.C.; U.S. Government Printing Office, 1965.

The revolutionary character of the newer technology of numerically controlled machining (studies E2, F2) resides in the substitution of automatic for manual control over the operation, once the workpiece has been clamped in position. N/C tools are equipped with control units which read data from punched-paper or magnetic tapes (prepared in advance with the aid of computers) and transmit electronic pulse signals to control the motions of the machine. All details of each operation as well as of the sequence of operations are programmed into the tape. Some of the more recent N/C tools include cutting-tool storage racks and manipulators: at the appropriate times pulse signals cause the rack to shift or rotate and simultaneously activate the manipulator to first detach the cutting tool no longer needed and replace it in its empty slot on the rack, and then extract the next tool required and transfer it to the cutting tool holder on the machine tool. Apart from arranging the jigs and fixtures holding the workpiece in place, threading the tape in the control unit and referencing the cutting tool, the operator acts only as a machine minder and monitor; these latter functions are liable to diminish further in importance with the introduction of feedback devices capable of compensating for cutting tool wear, vibrations and other random influences.

Activities connected with the actual preparation of the tapes have not been included in the skill-profiles since they do not represent direct labor. The total indirect labor time going into tape preparation, already relatively small per unit product, is in fact due to undergo further reduction as the procedures of programming become automatic, i.e., wholly performed by computer. For further details of these impending developments reference should be made to the Bureau of Labor Statistics report previously mentioned. (See footnote on page IV-1)

2. PROCESS DESCRIPTION

The parts manufactured in Firms E and F are components used in the construction of aircraft and/or missiles. Firm E operates as a subcontractor to other firms in the aerospace industry but does not itself manufacture complete aircraft or hold prime contracts.

Firm F is a prime contractor engaged in making missiles. In both cases the dimensions and other specifications for a part to be produced are provided in the form of a set of engineering drawings, with quality standards indicated by tolerances and statements of the required surface finish. The manufacturing process may be subject to A.I.D. inspection and approval, which also serves to determine quality standards.

The execution of the initial sub-contract for a given part (Firm E) or the production of the first batch (Firm F) requires

a) the development of a manufacturing method and associated "tool-kit"

b) the actual production of a given number of parts.

Both of these are paid for on a cost-plus basis under the prime contract, and the tangible products become the property of the government (or other purchaser) on completion. The "tool-kit" is then put into store pending receipt of further orders (Firm E) or decisions to produce further batches (Firm F).

A) Preparation

The "tool-kit", i.e. the special equipment needed to produce a given part includes:

1) Jigs and tools needed to secure and position the blank or semifinished part to the machine-tool during each successive operation, and cutting tools for the machining proper.

2) Planning and setup documents giving the sequence of operations and critical data for each, with detail drawings where necessary.

3) (Numerical Control only) A Data System (DATS) consisting of a set of tapes and associated documents embodying the program of commands used to guide the machining operations in coded digital format. This is made available to the production department together with copies of the drawings supplied by the prime contractor (Firm E) or design office (Firm F).

The "tool-kit" is the outcome of a series of decisions made by a planning committee and implemented by planning engineers, tool designers, and the toolroom which makes the necessary jigs and fixtures. The decision whether to use conventional or numerical-control (N/C) methods for each operation on a given part is taken by the planning committee early in their deliberations, and if N/C methods are to be used, the preparation of a Data System is delegated to the Numerical Control engineer and his staff. The DATS is treated as formally equivalent to another tool, but in practice the necessary parts-programming is a lengthy procedure involving several data conversions from drawing to coding-sheet to punched cards and finally to punched or magnetic tape. The programming is carried out in a symbolic language developed specially for the purpose as part of the Automatically Programmed Tools (APT) system, and the symbolically coded program is then compiled by a computer to yield the final control medium.

On completion of tooling (and DATS for N/C applications) one or more tool proving runs are conducted and the resulting parts are carefully measured to verify correctness of their dimensions, and errors of method or tooling are rectified before final approval.

Since the development of a manufacturing method is an overhead rather than a per-unit cost, differences in manpower requirements between conventional and N/C procedures have not been recorded precisely and do not figure in the comparative data of the report proper. However as an indication of relative magnitudes, some 100-200 manhours are typically required for planning, tooling and programming a single new part. Extra time required for parts-programming in the N/C case tends to be offset by reduced time for tool fabrication, since simpler fixtures can be employed, hence the use of N/C methods does not add markedly to the overheads.

B) Machining

Each part manufactured requires a different sequence of operations, and the detailed method within each operation varies greatly according to the type of machine employed even for the same nominal operation, e.g. milling. In general, conventional machining operations require a lengthy setup procedure involving assembly of jigs and lubricant lines, tools, fine setting of stops, patterns and other semi-automatic aids to precision machining, and measuring exact dimensions. After setup each successive workpiece is simply clamped in the prepared resting-place using previously established reference points and planes, and the machining proper is conducted by the manipulation of automatic feeds and drive-switches, with tool-changes as required. Operators may experience comparatively long periods of inactive monitoring while the automatic feed completes a cut.

There are major differences between so-called "point-to-point" and continuous-path machining. In the former which includes all drilling and boring operations, metal is removed at a number of distinct locations with tool-feed along a single axis in each case. Motions between point locations need not be accurately controlled, only the final coordinates and depth of cut being critical. In continuous-path machining the drawing specifies an arbitrary one, two or three-dimensional curvature which cannot be achieved by simple means and requires some form of continuous curve-following. Tracer-controlled tools achieve arbitrary curvature in one dimension by using a fixed template to guide a sensing element which in turn controls the motion of the tool. The traverse across the surface of the template is in a straight line under automatic feed, and it is possible to produce arbitrary two and three-dimensional curvatures by a sequence of parallel traverses across the template, provided there are no re-entrants.

Under numerical-control the path of the cutting tool is specified by a closely-spaced sequence of commands each giving one or more points on the desired approximation with no detailed control by the operator, and this is the major advantage of the N/C systems used in Firm E. In Firm F (but not E) N/C methods are also used for the relatively simpler "point-to-point" machining process, where they provide rapid and automatic tool-changing and operation of traverses, but their advantage over semiautomatic hand operation is less marked.

All the parts studied in both firms required hand-finishing, anodising and other ancillary operations after machining. These were largely unaffected by the adoption of N/C methods, with the exception that somewhat more hand-finishing was required in Firm E.

In Firm E most N/C machining operations were carried out with a single operator servicing two or more machine tools. In many cases setup operations for one part could be conducted within the automatic machining cycle(s) of the other(s) substantially reducing the per-unit manhour requirements. Agreement with the labor union on this method of working had been reached after arbitration, permitting the firm to realize a large part of the potential extra productivity available with N/C methods. Firm F had no such arrangement and a single operator monitored a single N/C machine throughout its cycle.

The two sequences of operations specified for one typical part manufactured in Firm F are given below, with the allowed times in hours. Calculations of manhour requirements by skill level were based on an assumed batch-size of 100 parts, and the quoted setup times should therefore be divided by this number to obtain time per part. The numbers in the column headed "Level of Mechanization" are based on J.R. Bright's scale (see Appendix I, II & III).

FIRM F PART 398 OPERATION SEQUENCE FOR CONVENTIONAL METHOD

				Allowed time (hours)		
	Operation	Machine or Tool	Operator	Setup (per batch)	Run (per piece)	Level of Mechanization
1.	Saw aluminium bar-stock to length	(hand tools)	Milling Machine Operator A	-	0.001	2
2.	Machine flats (4 operations)	"Small" Vertical milling machine	"	1.32	0.680	5
3.	Drill 3 holes, countersink, tap, ream	Multi-spindle drill press	Drill Press Operator A	1.00	0.710	4
4.	Mill one flat	"Small" Vertical milling machine	Milling Machine Operator A	0.32	0.480	5
5.	Break edges	(hand tools)	General factory Helper	0.10	0.030	2
6.	Identify	(hand tools)	"	0.1	0.005	2
7.	(Inspection 3 items)		"	-	-	-
8.	Mask, Anodise, demask	Anodising tank	"	0.1	0.005	3
9.	(Inspection 2 items)		"	-	-	2
10.	Apply coating	(hand tools)	"	-	0.003	3
11.	(Inspection 2 items)		"	-	-	-
12.	Identify by tag and wrap	hand	"		.001	1
13.	(Inspection 2 items)		"	-	-	

FIRM F PART 398 OPERATION SEQUENCE FOR N/C MACHINING

				Allowed Time (hours)		
	Operation	Machine or Tool	Operator	Setup (per batch)	Run (per piece)	Level of Mechanizati
1.	Saw aluminum bar-stock to length	(hand tools)	Milling Machine Operator A	-	0.001	2
2.	Machine flats (2 operations)	"Small" vertical milling machine (conventional tool)	"	0.68	0.109	5
3.	Break sharp edges	(hand tools)	General factory helper	0.10	0.011	2
4.	Machine 2 flats, drill, countersink, tap etc. under program control	Milmatic Series E. Numerical-control point-to-point horizontal milling machine	N/C milling machine operator	3.30	0.361	6
5.	Break sharp edges	(hand tools)	General factory helper	0.10	0.030	2
6.	Identify	(hand tools)	"	0.10	0.005	2
7.	(Inspection 3 items)	-	"	-	-	-
8.	Degrease	Degreasing tank	"	-	0.001	3
9.	Mask, Anodise, demask	Anodising tank	"	-	0.004	3
10.	(Inspection 2 items)	-	"	-	-	
11.	Mask, apply coating, demask	(hand tools)	"	-	0.003	3
12.	(Inspection 4 items)	-	"	-	-	
13.	Identify, wrap	(hand)	"	-	0.001	1

3. CALCULATION OF PROPORTION OF CYCLE TIME REPLACED BY NUMERICALLY CONTROLLED MACHINING

To determine the extent of substitution of N/C machining for conventional, the proportion of the conventional cycle time replaced by N/C machining was expressed as a percentage; the parts where this percentage fell below 66% were excluded from the study. The tables below contain the relevant information.

TABLE IV-1

FIRM E

Part	Cycle time, conventional machining	Amount of cycle time replaced by N/C	% of cycle time replaced by N/C
891	5.1 hours	3.5 hours	69%
141	2.4 "	1.9 "	80%
502 (excluded)	5.2 "	1.7 "	33%

TABLE IV-2

FIRM F

Part	Cycle time, conventional machining	Amount of cycle time replaced by N/C	% of cycle time replaced by N/C
549	2.7 hours	2.5 hours	93%
398	2.0 "	1.9 "	95%
601	5.0 "	3.6 "	72%
452	4.1 "	3.1 "	76%
389	4.5 "	3.5 "	78%
884	4.4 "	3.1 "	70%

4. CHARACTERISTICS OF PARTS SELECTED COMPARED WITH ALL PARTS PRODUCED BY FIRMS E & F

The tables in this section contrast the types of metal used and the estimated complexity of the parts selected in Firms E and F with those of all parts produced by conventional and N/C machining in both firms. The decisive selection criterion was the identity of the parts as between technologies.

The percentage of conventional machining replaced by N/C machining on each part is also shown (see preceding section).

TABLE IV-3

E1, CONVENTIONAL MACHINING

	Type of metal used		Complexity rating	
All parts produced	Aluminum	45%	1	25%
	Stainless Steel	45%	2	50%
	Steel	9%	3	25%
	Inconel	1%		
Parts selected 891	Stainless Steel		2 to 3	
141	Aluminum		2	

TABLE IV-4

E2, NUMERICALLY CONTROLLED MACHINING

	Type of metal used		Complexity rating	
All parts produced	Aluminum	50%	2	25%
	Steel	49%	3	50%
	Stainless Steel	1%	4	30%
Parts selected 891	Stainless Steel		2 to 3	
141	Aluminum		3	

Complexity rating 1 = least complex

Complexity rating 4 = most complex

TABLE IV-5

F1, CONVENTIONAL MACHINING

	Type of metal used	Complexity
All parts produced	Aluminum 60%	Average 50%
	Steel 30%	Above Average 30%
	Titanium 5%	Very Complex 20%
	Stainless Steel 5%	Very Complex 20%
Parts selected 549	Aluminum	Average
398	Aluminum	Average
601	Stainless Steel	Very Complex
452	Aluminum	Very Complex
389	Aluminum	Above Average
884	Aluminum	Very Complex

TABLE IV-6

F2, NUMERICALLY CONTROLLED MACHINING

	Type of metal used	Complexity
All parts produced	Aluminum 95%	Average 33%
	Stainless Steel 4%	Above Average 33%
	Titanium 1%	Very Complex 33%
Parts selected 549	Aluminum	Average
398	Aluminum	Average
601	Stainless Steel	Very Complex
452	Aluminum	Very Complex
389	Aluminum	Above Average
884	Aluminum	Very Complex

5. METHOD OF DERIVING SKILL LEVEL VALUES FROM JOB EVALUATION SCHEMES

Firm E

Identical criteria are applied under this firm's job evaluation scheme to all jobs whether they involve the use of conventional or numerically controlled machine tools.

There are five factors on which evaluations are made of every job:

SKILL - (Training, Precision, Concentration & Dexterity)

MENTAL REQUIREMENTS

Responsibility

Working Conditions

Physical Conditions

The four components of the SKILL factor are defined as follows:

Training: "Total time required for sufficient training and experience and to become proficient in performance". This component is assigned 16 possible values, in the range 280.0 - 510.0.

Precision: "Extent of tolerances to be held"; 12 discrete values in the range 1.25 - 15.5.

Concentration: "Intensity, frequency and continuity of concentration required"; 9 discrete values in the range 1.5 - 14.0.

Dexterity: "Manual dexterity and muscular coordination required"; 4 discrete values in the range 2.0 - 8.0.

The MENTAL REQUIREMENTS factor is defined as "Ability to understand, visualize and interpret technical data such as blueprints, work orders and other types of authorized documents; kind and amount of work instruction and degree of supervision, knowledge required such as algebra, geometry, trigonometry and familarity with shop procedures and materials". This factor carries 20 distinct point values in the range 50 - 165.

It will be noted that training, experience and mental requirements are relatively heavily weighted in the total measure of skill used in this report (comprising the sum of point-scores for SKILL and MENTAL REQUIREMENTS), precision and concentration somewhat less; and dexterity least.

By agreement with the labor union, rates of pay after an initial period as "Learner" were determined by labor grades ranked 1 (highest) through 15

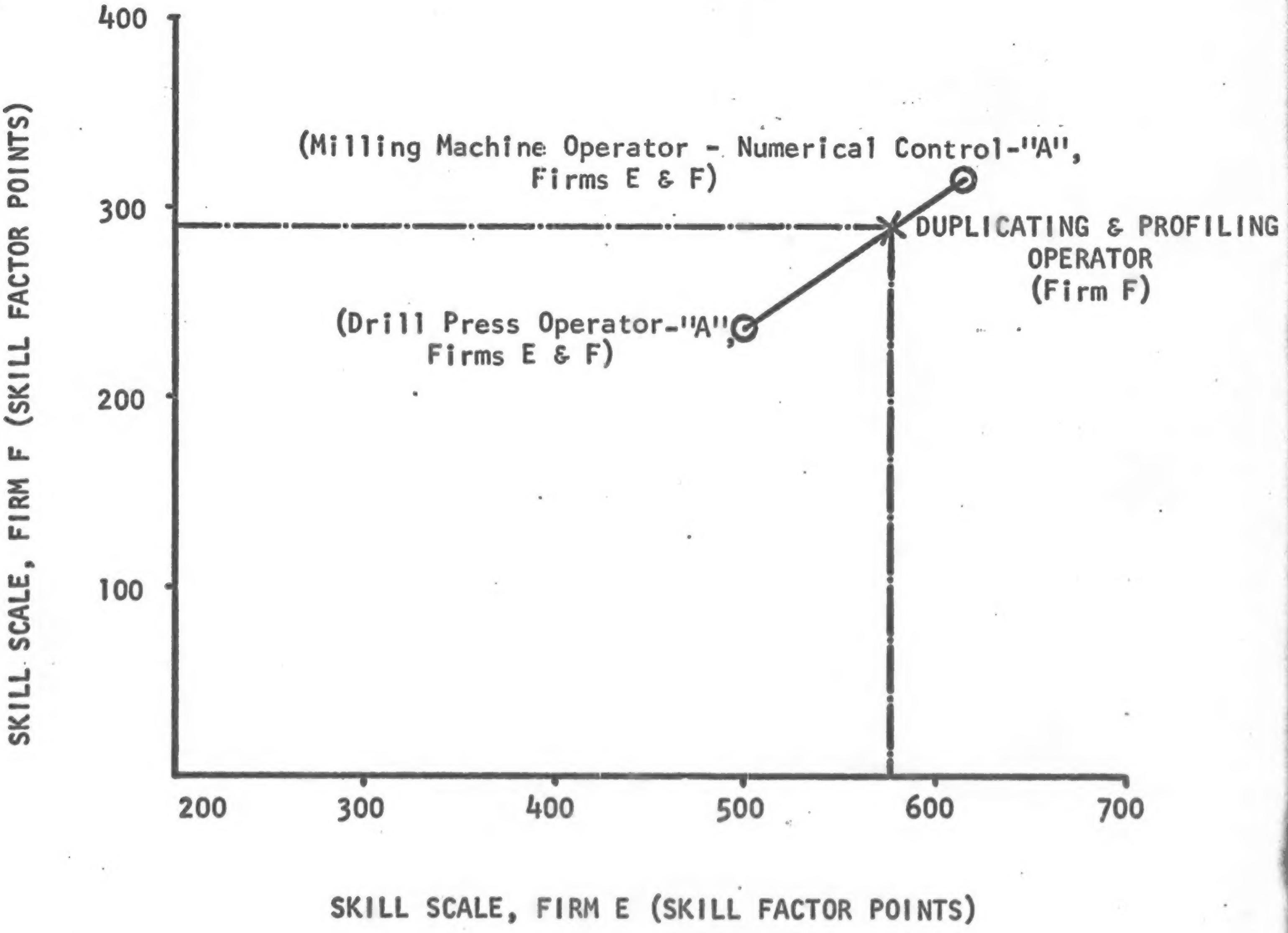
6. TRANSLATION OF FIRM F INTO FIRM E SCORES

As in the case of the two bank systems, the skill scores were standardized by transforming the skill scores of all Firm F jobs into the Firm E scale. This proved a simple matter as the titles and descriptions of 5 jobs in Firm F were nearly identical with 5 jobs in Firm E; a further 5 jobs in Firm F, though not matched by jobs of similar content in Firm E, had point scores for which there were corresponding scores on the Firm E scale, as shown below:

Job (Firm F)	Skill Points	Job (Firm E)	Skill Points on Joint Scale
Factory Helper General	77	Burrer Hand	396
Drill Press Operator A	243	Drill Press Operator A	500
Milling Machine Operator NC - A	314	Milling Machine Operator NC - A	615
Milling Machine Operator A	314	Milling Machine Operator A	615
Milling Machine Machinist	393	Milling Machine Machinist	670
Engine Lathe Operator A	314	-	615
Duplicating & Profiling Machinist	393	-	670
Jig Borer Machinist	393	-	670
Lathe Machinist	393	-	670
Duplicating & Profiling Operator	390	-	576

The point score for one remaining Firm F job (Duplicating and Profiling Operator) was arrived at by interpolation (point X, in Figure IV-1).

FIGURE IV-1: GRAPH FOR CONVERTING FIRM F TO FIRM E SKILL POINT RATINGS



5. METHOD OF DERIVING SKILL LEVEL VALUES FROM JOB EVALUATION SCHEMES

Firm E

Identical criteria are applied under this firm's job evaluation scheme to all jobs whether they involve the use of conventional or numerically controlled machine tools.

There are five factors on which evaluations are made of every job:

SKILL - (Training, Precision, Concentration & Dexterity)

MENTAL REQUIREMENTS

Responsibility

Working Conditions

Physical Conditions

The four components of the SKILL factor are defined as follows:

Training: "Total time required for sufficient training and experience and to become proficient in performance". This component is assigned 16 possible values, in the range 280.0 - 510.0.

Precision: "Extent of tolerances to be held"; 12 discrete values in the range 1.25 - 15.5.

Concentration: "Intensity, frequency and continuity of concentration required"; 9 discrete values in the range 1.5 - 14.0.

Dexterity: "Manual dexterity and muscular coordination required"; 4 discrete values in the range 2.0 - 8.0.

The MENTAL REQUIREMENTS factor is defined as "Ability to understand, visualize and interpret technical data such as blueprints, work orders and other types of authorized documents; kind and amount of work instruction and degree of supervision, knowledge required such as algebra, geometry, trigonometry and familarity with shop procedures and materials". This factor carries 20 distinct point values in the range 50 - 165.

It will be noted that training, experience and mental requirements are relatively heavily weighted in the total measure of skill used in this report (comprising the sum of point-scores for SKILL and MENTAL REQUIREMENTS), precision and concentration somewhat less; and dexterity least.

By agreement with the labor union, rates of pay after an initial period as "Learner" were determined by labor grades ranked 1 (highest) through 15 (lowest). These were based on job evaluation in the manner indicated above, including all five factors. Since the skill measures reported here were derived from a more restricted evaluation using two selected factors only, the skill rankings given in the tables below may differ significantly from rankings by labor grade, reflecting the specific focus of this study on skills, rather than general effectiveness, responsibility and value to the firm.

Firm F

In this firm, too, identical criteria are used for rating conventional machining and numerical control machining jobs.

Seven factors are used for evaluations:

SKILL

MENTALITY

Responsibility for material and equipment

Mental application

Physical application

Job conditions

Unavoidable hazards

The first two factors which were used in the study are defined as:

SKILL: "The technique necessary for the satisfactory performance of the job as measured by the length of time normally required for an average individual of normal mental capacity to acquire the necessary trade, knowledge and training". 14 distinct values are possible in the range 40 - 400.

MENTALITY: "The prerequisite mental capacity necessary to learn to perform a given job efficiently". 5 values are possible, in the range 20 - 100.

7. RAW DATA USED FOR THE DEVELOPMENT OF SKILL PROFILES

The following notes refer to the individual columns of the tables in this section.

Job Code:	The codes are internal codes, assigned to each job to facilitate cross referencing. The letter identifies the firm, the attached figure identifies technology and the figure separated by a dash, the job.
Job D.O.T. No.:	These six digit numbers are taken from the 1965 Dictionary of Occupational Titles. The matching of D.O.T. number and job was done by the researchers on the basis of job description and their own knowledge of the jobs.
Job Title:	Official titles assigned to the jobs by the firm.
Skill Level:	Total skill factor points for each job derived from the job evaluation schemes used in Firms E and F. The transformations of Firm F skill factor points into the corresponding points on the Firm E scale (see Section 6) are shown in the column "Translated Skill Level".
Manhours:	Figures corresponding to set-up time Ⓢ for a specified lot of parts and run times Ⓡ per part were taken directly from production sheets.
Lot Size:	Estimates of the average number of parts produced in each batch for the parts in question supplied by planning personnel within each firm.

FIRM E: MACHINING - 2 PARTS

E1 CONVENTIONAL MACHINING

Job Code	Job D.O.T. No.	Job Title	Skill Level	Part 891		Part 141	
				Ⓢ 100 Parts	Ⓡ	Ⓢ 160 Parts	Ⓡ
E1-1	606.782	Drill Press Operator - B	435	-	-	0.5600	0.0293
E1-2	705.884	Machine Parts Filer and Burrer	455	0	0.1142	0	0.3490
E1-3	605.782	Milling Machine Operator - B	555	2.499	1.0350	0.5600	0.0520
E1-4	606.782	Drill Press Operator - A	500	0.497	0.6880	0.6700	0.0258
E1-5	705.884	Hand Finisher - Precision - B	525	0	0.2500	-	-
E1-6	605.782	Milling Machine Operator - A	615	4.5000	2.9500	8.9100	1.0913
E1-7	606.380	Radial Drill Press Operator - A	565	-	-	0.3000	0.1000
E1-8	605.782	Milling Machine Machinist	670	-	-	3.7500	0.6375

E2 NUMERICAL CONTROL MACHINING

Job Code	Job D.O.T. No.	Job Title	Skill Level	Part 891		Part 141	
				Ⓢ 100 Parts	Ⓡ	Ⓢ 160 Parts	Ⓡ
E2-1	705.884	Burrer - Hand	396	-	-	0	0.3329
E2-2	705.884	Machine Parts Filer and Burrer	455	0	0.0141	0	0.0281
E2-3	605.782	Milling Machine Operator - B	555	2.4990	0.1614	-	-
E2-4	606.782	Drill Press Operator - A	500	0.5300	0.5483	1.1300	0.0895
E2-5	705.884	Hand Finisher - Precision - B	525	0	0.2785	-	-
E2-6	606.782	Drilling Machine Operator-Numerical Control	565	-	-	0.8400	0.0404
E2-7	609.782	Milling Machine Operator-Numerical Control - A	615	0	1.9027	0	1.4426
E2-8	605.782	Milling Machine Operator - A	615	1.0000	0.5000	-	-

NOTE: Ⓢ is set up time in manhours for the number of parts shown.

Ⓡ is run time per part in manhours.

FIRM F: MACHINING - 6 PARTS

F1 CONVENTIONAL MACHINING

Job Code	Job D.O.T. No.	Job Title	Firm F Skill Level	Translated Skill Level	Part 549		Part 398		Part 601		Part 452		Part 389		Part 884	
					Ⓢ 30 Parts	Ⓡ	Ⓢ 30 Parts	Ⓡ	Ⓢ 30 Parts	Ⓡ	Ⓢ 30 Parts	Ⓡ	Ⓢ 30 Parts	Ⓡ	Ⓢ 30 Parts	Ⓡ
F1-1	804.886	Factory Helper General	77	396	0.400	0.032	0.200	0.035	0.400	0.106	0.300	0.059	0.400	0.079	0.200	0.013
F1-2	606.782	Drill Press Operator -A	243	500	0.450	0.050	1.000	0.710	0.380	0.250	0.740	0.425	1.180	0.330	0.900	0.300
F1-3	615.782	Duplicating and Profiling Operator	290	576	-	-	-	-	-	-	-	-	4.800	1.590	-	-
F1-4	605.782	Milling Machine Operator -A	314	615	3.390	2.490	1.640	1.160	0.720	0.340	2.480	0.502	1.650	0.417	-	-
F1-5	604.280	Engine Lathe Operator - A	314	615	-	-	-	-	1.100	0.890	-	-	-	-	1.100	1.090
F1-6	605.782	Milling Machine Machinist	393	670	-	-	-	-	-	-	0.440	0.039	2.440	1.690	8.400	2.010
F1-7	615.782	Duplicating and Profiling Machinist	393	670	-	-	-	-	-	-	4.000	0.840	-	-	2.400	0.574
F1-8	606.280	Jig Borer Machinist	393	670	-	-	-	-	1.600	3.300	3.260	1.866	-	-	-	-

F2 NUMERICAL CONTROL MACHINING

Job Code	Job D.O.T. No.	Job Title	Firm F Skill Level	Translated Skill Level	Part 549		Part 398		Part 601		Part 452		Part 389		Part 884	
					Ⓢ 30 Parts	Ⓡ	Ⓢ 30 Parts	Ⓡ	Ⓢ 30 Parts	Ⓡ	Ⓢ 30 Parts	Ⓡ	Ⓢ 30 Parts	Ⓡ	Ⓢ 30 Parts	Ⓡ
F2-1	804.886	Factory Helper General	77	396	0.500	0.156	0.300	0.046	0.400	0.057	0.400	0.189	0.400	0.084	0.400	0.232
F2-2	606.782	Drill Press Operator -A	243	500	0.580	0.050	-	-	0.380	0.250	-	-	1.560	0.354	1.020	0.369
F2-3	605.782	Milling Machine Operator -A	314	615	-	-	0.680	0.109	-	-	-	-	0.680	0.307	-	-
F2-4	604.280	Engine Lathe Operator -A	314	615	-	-	-	-	1.100	0.890	-	-	-	-	-	-
F2-5	609.782	Numerical Control Milling Mach. Oper.	314	615	6.080	1.012	3.300	0.361	4.400	0.411	10.400	1.602	4.700	0.792	3.500	1.782
F2-6	605.782	Milling Machine Machinist	393	670	-	-	-	-	-	-	-	-	0.560	0.120	-	-
F2-7	604.280	Lathe Machinist	393	670	-	-	-	-	-	-	-	-	-	-	1.500	0.620
F2-8	606.280	Jig Borer Machinist	393	670	-	-	-	-	0.800	0.077	2.300	0.694	-	-	-	-

NOTE: Ⓢ is set up time in manhours for the number of parts shown.

Ⓡ is run time per part in manhours.

8. LENGTH OF OPERATORS' GENERAL EDUCATION AND ON-THE-JOB EXPERIENCE

The internal job codes and job titles used in Section 7 are retained to facilitate cross-referencing.

Estimates of general educational requirements made by researchers.

Estimates of on-the-job experience requirements supplied by firms.

FIRM E: MACHINING - 2 PARTS

Job Code	Job Title	Estimated Required General Education (Years of High School) 0	1-2	3-4	On-the-job Experience (Months) 6	12	18	24	30	36	44
E1 CONVENTIONAL MACHINING											
E1-1	Drill Press Operator - B			X	X						
E1-2	Machine Parts Filer and Burrer			X	X						
E1-3	Milling Machine Operator - B			X		X					
E1-4	Drill Press Operator - A			X				X			
E1-5	Hand Finisher - Precision - B			X	X						
E1-6	Milling Machine Operator - A			X						X	
E1-7	Radial Drill Press Operator - A			X				X			
E1-8	Milling Machine Machinist			X							X
E2 NUMERICAL CONTROL MACHINING											
E2-1	Burrer - Hand	X			X						
E2-2	Machine Parts Filer and Burrer			X	X						
E2-3	Milling Machine Operator - B			X		X					
E2-4	Drill Press Operator - A			X				X			
E2-5	Hand Finisher - Precision - B			X	X						
E2-6	Drilling Machine Operator - Numerical Control			X				X			
E2-7	Milling Machine Operator - Numerical Control - A			X				X			
E2-8	Milling Machine Operator - A			X						X	

FIRM F: MACHINING - 6 PARTS

Job Code	Job Title	Estimated Required General Education (Years of High School)			On-the-job Experience (Months)				
		0	1-2	3-4	1	18	24	30	48
F1 CONVENTIONAL MACHINING									
F1-1	Factory Helper General	X			X				
F1-2	Drill Press Operator - A			X		X			
F1-3	Duplicating and Profiling Operator			X			X		
F1-4	Milling Machine Operator - A			X				X	
F1-5	Engine Lathe Operator - A			X				X	
F1-6	Milling Machine Machinist			X					X
F1-7	Duplicating and Profiling Machinist			X					X
F1-8	Jig Borer Machinist			X					X
F2 NUMERICAL CONTROL MACHINING									
F2-1	Factory Helper General	X			X				
F2-2	Drill Press Operator - A			X		X			
F2-3	Milling Machine Operator - A			X				X	
F2-4	Engine Lathe Operator - A			X				X	
F2-5	Numerical Control Milling Machine Operator			X				X	
F2-6	Milling Machine Machinist			X					X
F2-7	Lathe Machinist			X					X
F2-8	Jig Borer Machinist			X					X

9. COMPARATIVE SKILL DISTRIBUTION TABLES AND SKILL PROFILES FOR INDIVIDUAL PARTS PRODUCED BY FIRMS E AND F

Note: The data for part #502 (Firm E) shown in Table IV-9 and in Figure IV-4 were excluded from the main analysis as the percentage of conventional machining replaced by numerical control failed to meet the minimum criterion.

TABLE IV-7

COMPARATIVE SKILL DISTRIBUTIONS - of Individual Component #891

Organization: Aerospace Firm E

Process: Machining Component No. 891

Technology (Level 1): Conventional Machining

Technology (Level 2): Numerically Controlled Machining
(55.2% of Total TL2 Manhours)

Source of Data: Direct Observation

Period: Fall 1965

1		2	3	4	5	6	7	8	9	10	11
SKILL LEVEL		SKILL POINT RANGE	MANHOURS PER PART			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
			TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG
High	6										
	5	640-699	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	4	580-639	3.0	2.4	-0.6	58.8	70.4	+11.6	1	1	0
Medium	3	520-579	1.3	0.5	-0.8	25.5	14.7	-10.8	2	2	0
	2	460-519	0.7	0.5	-0.2	13.7	14.7	+ 1.0	1	1	0
Low	1	400-459	0.1	0.01	-0.1	2.0	0.2	-1.8	1	1	0
	0	340-399	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
		TOTALS	5.1	3.4	-1.7	100	100		5	5	0
		NET % MANHOUR CHANGE		-33.3%							

	Mean Skill Level	Standard Deviation
Technology (Level 1)	579.0	47.0
Technology (Level 2)	585.3	46.9
Change	+6.3	

TABLE IV-8

COMPARATIVE SKILL DISTRIBUTIONS - For Individual Component #141

Organization: Aerospace Firm E

Process: Machining Component No. 141

Technology (Level 1): Conventional Machining

Technology (Level 2): Numerically Controlled Machining
(76.3% of Total TL2 Manhours)

Source of Data: Direct Observation

Period: Fall 1965

1	2	3	4	5	6	7	8	9	10	11
SKILL LEVEL	SKILL POINT RANGE	MANHOURS PER PART			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
		TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG.
High 6										
5	640-699	0.7	0.0	-0.7	29.2	0.0	-29.2	1	-	-1
4	580-639	1.1	1.4	+0.3	45.8	74.5	+28.7	1	1	0
Medium 3	520-579	0.2	0.05	-0.1	8.3	2.7	- 5.6	2	1	1
2	460-519	0.03	0.1	+0.1	0.0	5.3	+ 5.3	1	1	0
Low 1	400-459	0.4	0.03	-0.4	16.7	1.6	-15.1	2	1	-1
0	340-399	0.0	0.3	+0.3	0.0	16.0	+16.0	-	1	+1
	TOTALS	2.4	1.9	-0.5	100.0	100.0		7	5	-2
	NET % MANHOUR CHANGE	-20.8%								

	Mean Skill Level	Standard Deviation
Technology (Level 1)	599.3	71.8
Technology (Level 2)	568.3	84.3
Change	31.0	

TABLE IV-9

COMPARATIVE SKILL DISTRIBUTIONS - For Individual Component #502

Organization: Aerospace Firm E

Process: Machining Component No. 502**

Technology (Level 1): Conventional Machining

Technology (Level 2): Numerically Controlled Machining (30.5% of Total TL2 Manhours)

Source of Data: Direct Observation

Period: Fall 1965

1		2	3	4	5	6	7	8	9	10	11
SKILL LEVEL		SKILL POINT RANGE	MANHOURS PER PART			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
			TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG.
High	6										
	5	640-699	0.0	0.3	+0.3	0.0	5.9	+5.9	-	1	+1
	4	580-639	1.5	1.8	+0.3	28.3	35.3	+7.0	1	1	0
Medium	3	520-579	2.1	2.3	+0.2	39.6	45.1	+5.5	3	2	-1
	2	460-519	0.3	0.1	-0.2	5.7	2.0	-3.7	1	1	0
Low	1	400-459	1.3	0.4	-0.9	24.5	7.8	-16.7	1	1	0
	0	340-399	0.1	0.2	+0.1	1.9	3.9	+ 2.0	1	1	0
		TOTALS	5.3	5.1	-0.2	100.0	100.0		7	7	0
		NET % MANHOUR CHANGE -3.8%									

	Mean Skill Level	Standard Deviation
Technology (Level 1)	543.1	63.3
Technology (Level 2)	559.2	68.9
Change	+16.1	

** Excluded from main analysis: Percentage of conventional machining replaced by numerically controlled machining did not meet minimum criterion.

TABLE IV-10

COMPARATIVE SKILL DISTRIBUTIONS - For Individual Component #549

Organization: Aerospace Firm F

Process: Machining Component No. 549

Technology (Level 1): Conventional Machining

Technology (Level 2): Numerically Controlled Machining (83.4% of Total TL2 Manhours)

Source of Data: Direct Observation

Period: Fall 1965

1	2	3	4	5	6	7	8	9	10	11
SKILL LEVEL	SKILL POINT RANGE	MANHOURS PER PART			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
		TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG
High 6										
5	640-699	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
4	580-639	2.6	1.2	-1.4	96.3	80.0	-16.3	1	1	0
Medium 3	520-579	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
2	460-519	0.1	0.1	0.0	3.7	6.7	+3.0	1	1	0
Low 1	400-459	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
0	340-399	0.04	0.2	+0.2	0.0	13.3	+13.3	1	1	0
	TOTALS	2.7	1.5	-1.2	100.0	100.0	0.0	3	3	0
	NET % MANHOUR CHANGE			-44.4%						

	Mean Skill Level	Standard Deviation
Technology (Level 1)	608.6	32.8
Technology (Level 2)	583.6	73.0
Change	-25.0	

TABLE IV-11

COMPARATIVE SKILL DISTRIBUTIONS - For Individual Component #398

Organization: Aerospace Firm F

Process: Machining Component No. 398

Technology (Level 1): Conventional Machining

Technology (Level 2): Numerically Controlled Machining
(82.4% of Total TL2 Manhours)

Source of Data: Direct Observation

Period: Fall 1965

1		2	3	4	5	6	7	8	9	10	11
SKILL LEVEL		SKILL POINT RANGE	MANHOURS PER PART			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
			TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG.
High	6										
	5	640-699	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	4	580-639	1.2	0.6	-0.6	63.2	85.7	+22.5	1	1	0
Medium	3	520-579	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	2	460-519	0.7	0.0	-0.7	36.8	0.0	-36.8	1	-	-1
Low	1	400-459	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	0	340-399	0.04	0.1	+0.1	0.0	14.3	+14.3	1	1	0
		TOTALS	1.9	0.7	-1.2	100.0	100.0	0.0	3	2	-1
		NET % MANHOUR CHANGE -63.2%									

	Mean Skill Level	Standard Deviation
Technology (Level 1)	567.7	60.6
Technology (Level 2)	596.4	61.1
Change	+28.7	

TABLE IV-12

COMPARATIVE SKILL DISTRIBUTIONS - For Individual Component #601

Organization: Aerospace Firm F

Process: Machining Component No. 601

Technology (Level 1): Conventional Machining

Technology (Level 2): Numerically Controlled Machining
(28.1% of Total TL2 Manhours)

Source of Data: Direct Observation

Period: Fall 1965

1		2	3	4	5	6	7	8	9	10	11
SKILL LEVEL		SKILL POINT RANGE	MANHOURS PER PART			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
			TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG.
High	6										
	5	640-699	3.4	0.1	-3.3	66.7	5.0	-61.7	1	1	0
	4	580-639	1.3	1.5	+0.2	25.5	75.0	+49.5	1	1	0
Medium	3	520-579	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	2	460-519	0.3	0.3	0.0	5.9	15.0	+ 9.1	1	1	0
Low	1	400-459	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	0	340-399	0.1	0.1	0.0	1.9	5.0	+3.1	1	1	0
		TOTALS	5.1	2.0	-3.1	100.0	100.0	0.0	4	4	0
		NET % MANHOUR CHANGE		-60.8%							

	Mean Skill Level	Standard Deviation
Technology (Level 1)	640.5	56.6
Technology (Level 2)	587.3	67.2
Change	-53.2	

TABLE IV-13

COMPARATIVE SKILL DISTRIBUTIONS - For Individual Component #452

Organization: Aerospace Firm F

Process: Machining of Component No. 452

Technology (Level 1): Conventional Machining

Technology (Level 2): Numerically Controlled Machining (66.7% of Total TL2 Manhours)

Source of Data: Direct Observation

Period: Fall 1965

1		2	3	4	5	6	7	8	9	10	11
SKILL LEVEL		SKILL POINT RANGE	MANHOURS PER PART			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
			TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG
High	6										
	5	640-699	3.0	0.8	-2.2	73.2	27.6	-45.6	1	1	0
	4	580-639	0.6	1.9	+1.3	14.6	65.5	+50.9	1	1	0
Medium	3	520-579	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	2	460-519	0.4	0.0	-0.4	9.8	0.0	- 9.8	1	-	-1
Low	1	400-459	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
	0	340-399	0.1	0.2	+0.1	2.4	6.9	+4.5	1	1	0
		TOTALS	4.1	2.9	-1.2	100.0	100.0		4	3	-1
		NET % MANHOUR CHANGE -29.3%									

	Mean Skill Level	Standard Deviation
Technology (Level 1)	638.9	62.4
Technology (Level 2)	614.3	64.2
Change	-24.6	

TABLE IV-14

COMPARATIVE SKILL DISTRIBUTIONS - For Individual Component #389

Organization: Aerospace Firm F

Process: Machining Component No. 389

Technology (Level 1): Conventional Machining

Technology (Level 2): Numerically Controlled Machining
(48.6% of Total TL2 Manhours)

Source of Data: Direct Observation

Period: Fall 1965

1	2	3	4	5	6	7	8	9	10	11
SKILL LEVEL	SKILL POINT RANGE	MANHOURS PER PART			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
		TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG.
High 6										
5	640-699	1.8	0.1	-1.7	40.0	5.3	-34.7	1	1	0
4	580-639	0.5	1.3	+0.8	11.1	68.4	+57.3	1	1	0
Medium 3	520-579	1.7	0.0	-1.7	37.8	0.0	-37.8	1	-	-1
2	460-519	0.4	0.4	0.0	8.9	21.1	+12.2	1	1	0
Low 1	400-459	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
0	340-399	0.1	0.1	0.0	2.2	5.2	+ 3.0	1	1	0
	TOTALS	4.5	1.9	-2.6	100.0	100.0	0.0	5	4	-1
	NET % MANHOUR CHANGE			-57.8%						

	Mean Skill Level	Standard Deviation
Technology (Level 1)	607.5	61.9
Technology (Level 2)	583.6	66.8
Change	-23.9	

TABLE IV-15

COMPARATIVE SKILL DISTRIBUTIONS - For Individual Component #884

Organization: Aerospace Firm F

Process: Machining Aircraft Component No. 884

Technology (Level 1): Conventional Machining

Technology (Level 2): Numerically Controlled Machining
(59.0% of Total TL2 Manhours)

Source of Data: Direct Observation

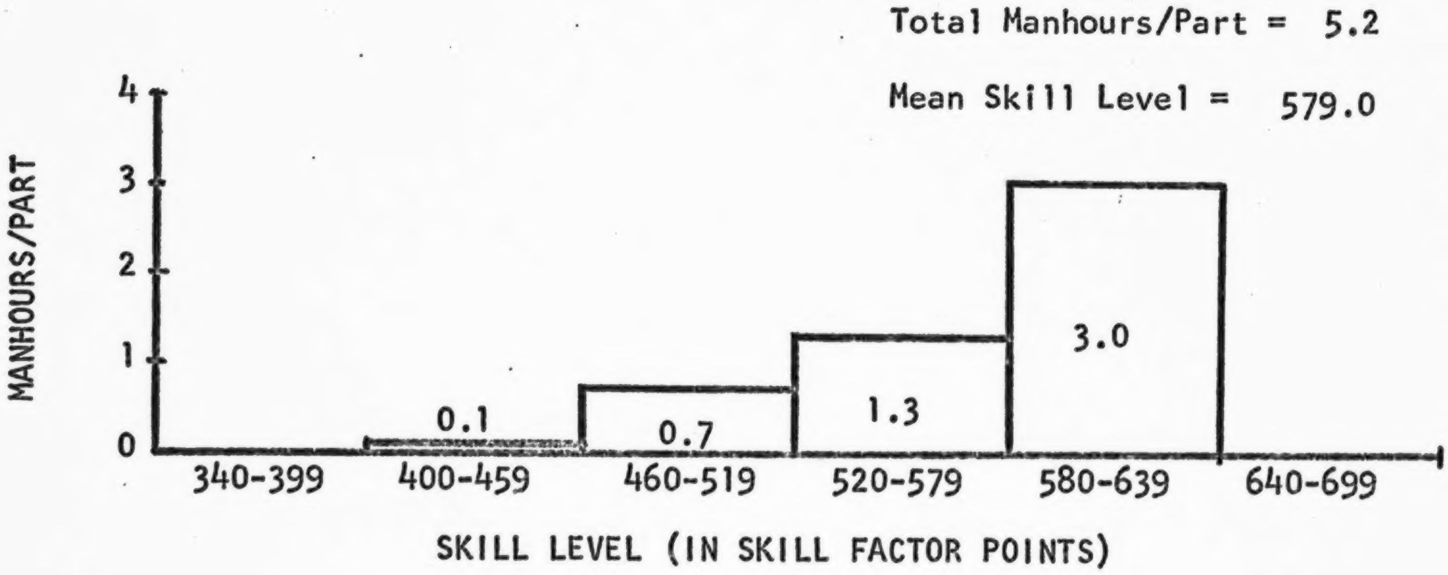
Period: Fall 1965

1	2	3	4	5	6	7	8	9	10	11
SKILL LEVEL	SKILL POINT RANGE	MANHOURS PER PART			MANHOURS AS % OF TOTAL FOR TECHNOLOGY LEVEL			NO. OF JOB TYPES		
		TL 1	TL 2	CHG.	TL 1	TL 2	CHG.	TL 1	TL 2	CHG
High 6										
High 5	640-699	2.9	0.7	-2.2	67.4	21.9	-37.5	1	1	0
High 4	580-639	1.1	1.9	+0.8	25.6	59.4	-33.8	1	1	0
Medium 3	520-579	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
Medium 2	460-519	0.3	0.4	+0.1	7.0	12.5	+ 5.5	1	1	0
Low 1	400-459	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-
Low 0	340-399	0.0	0.2	+0.2	0.0	6.2	+ 6.2	1	1	0
	TOTALS	4.3	3.2	-1.1	100.0	100.0		4	4	0
	NET % MANHOUR CHANGE	-25.6%								

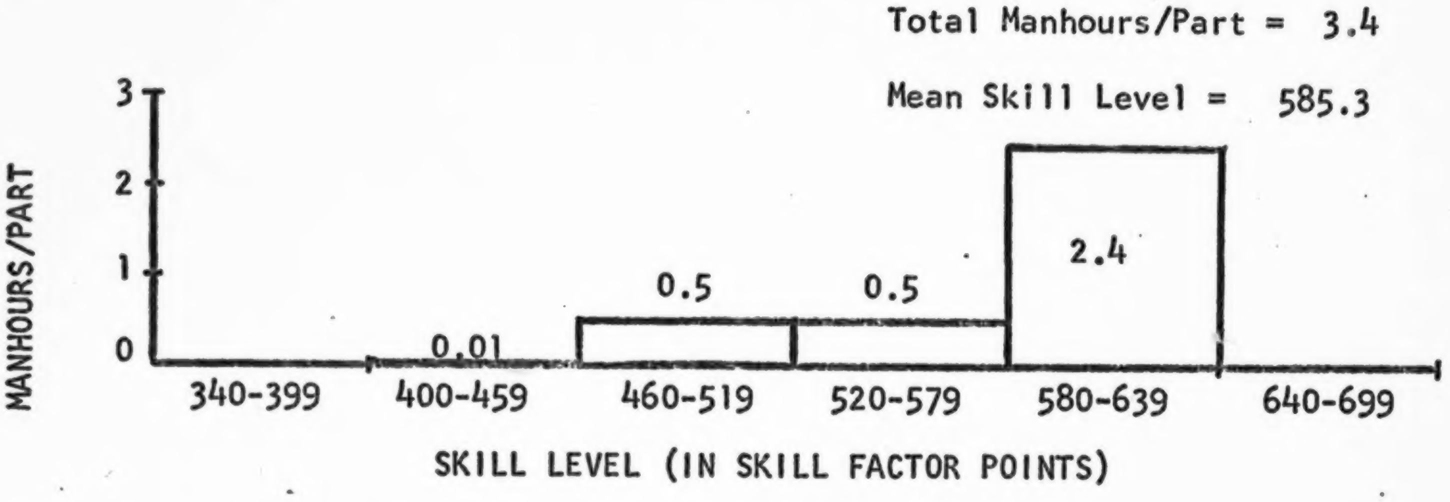
	Mean Skill Level	Standard Deviation
Technology (Level 1)	642.1	49.8
Technology (Level 2)	595.3	74.6
Change	-46.8	

FIGURE IV-2: COMPARATIVE SKILL PROFILES FOR PART #891 (Firm E)

CONVENTIONAL MACHINING



N/C MACHINING



CHANGES - OLD TO NEW TECHNOLOGY

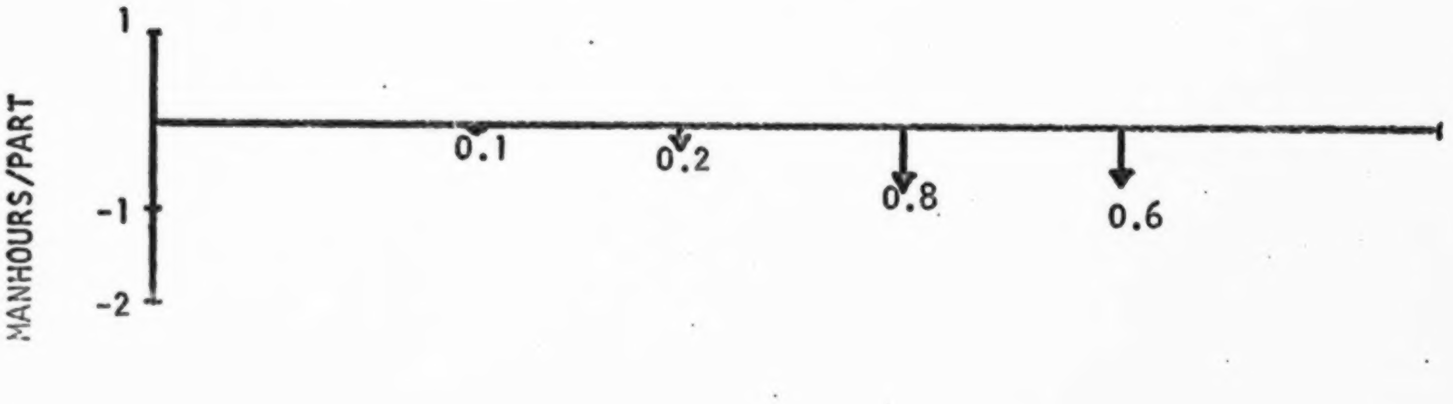
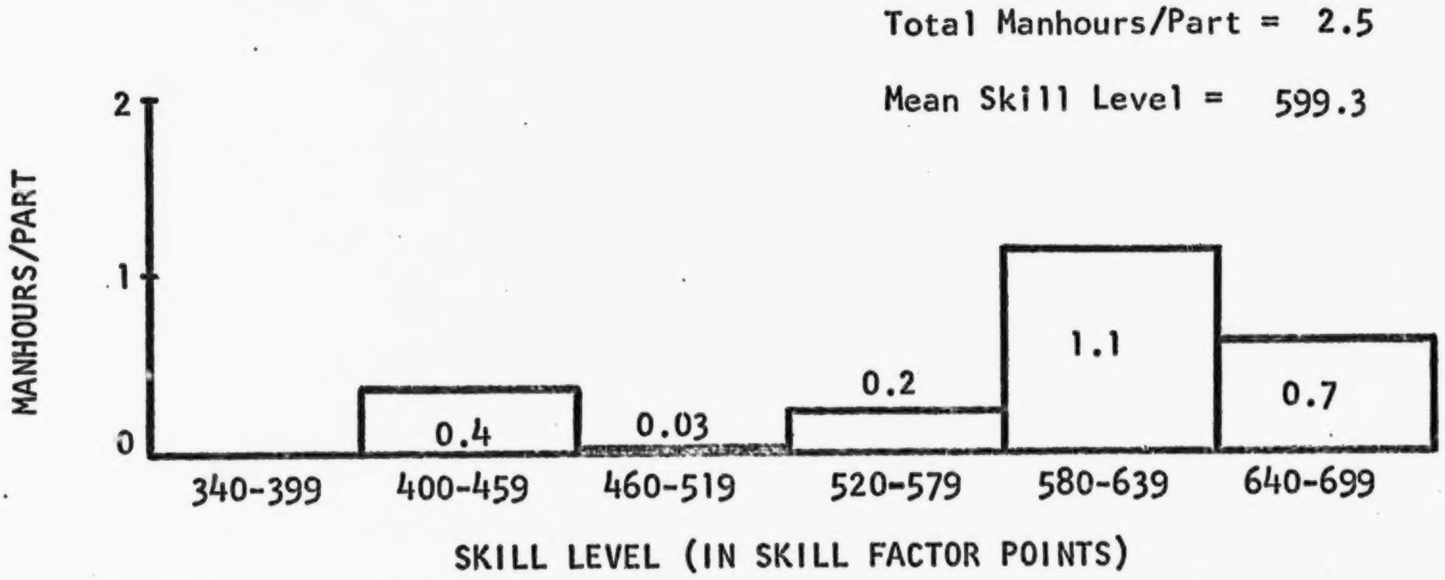
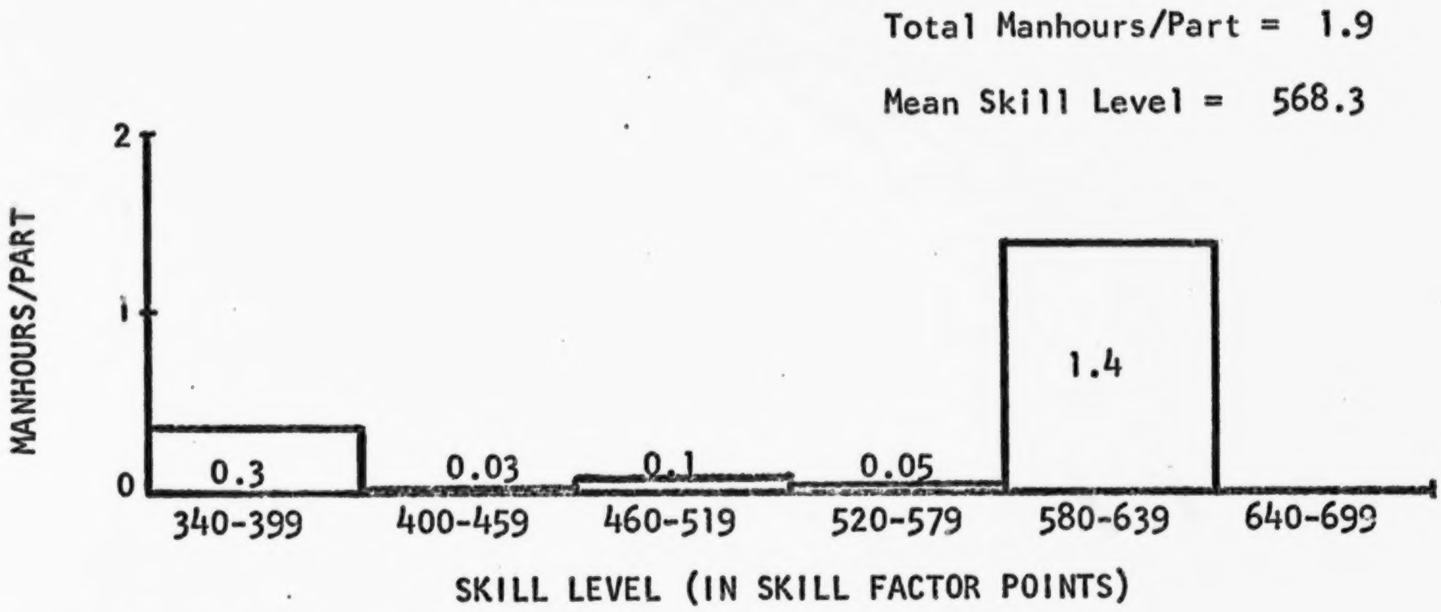


FIGURE IV-3: COMPARATIVE SKILL PROFILES FOR PART #141 (Firm E)

CONVENTIONAL MACHINING



N/C MACHINING



CHANGES - OLD TO NEW TECHNOLOGY

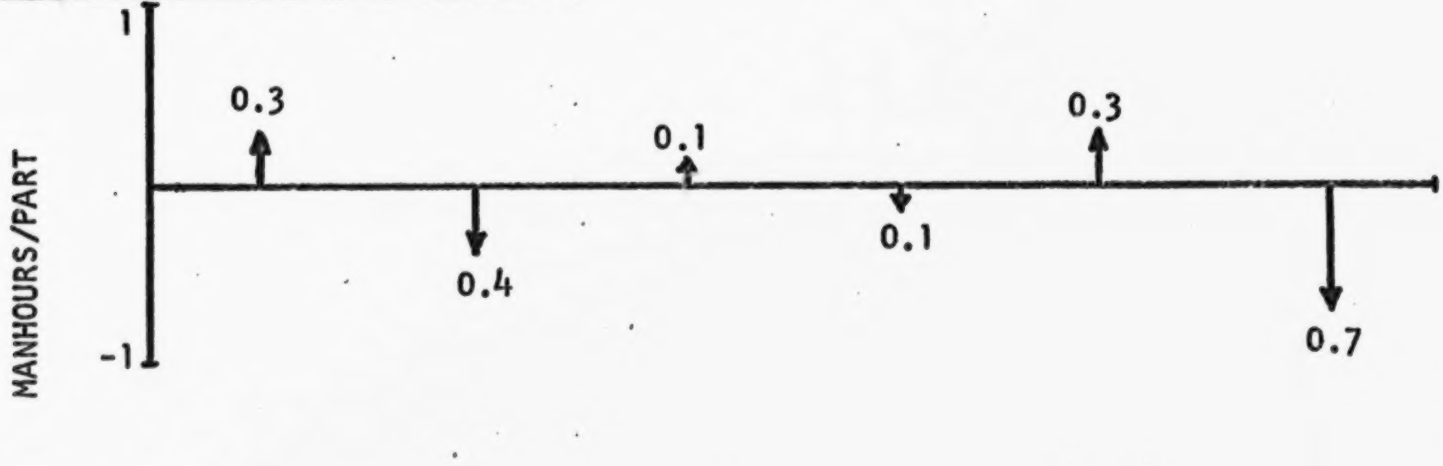
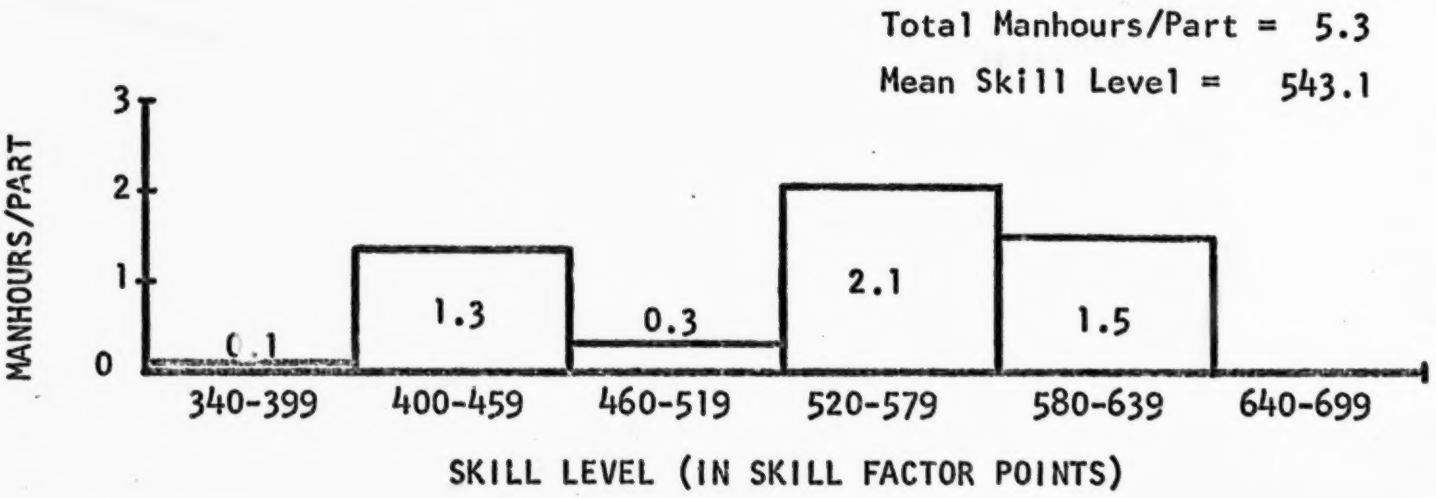
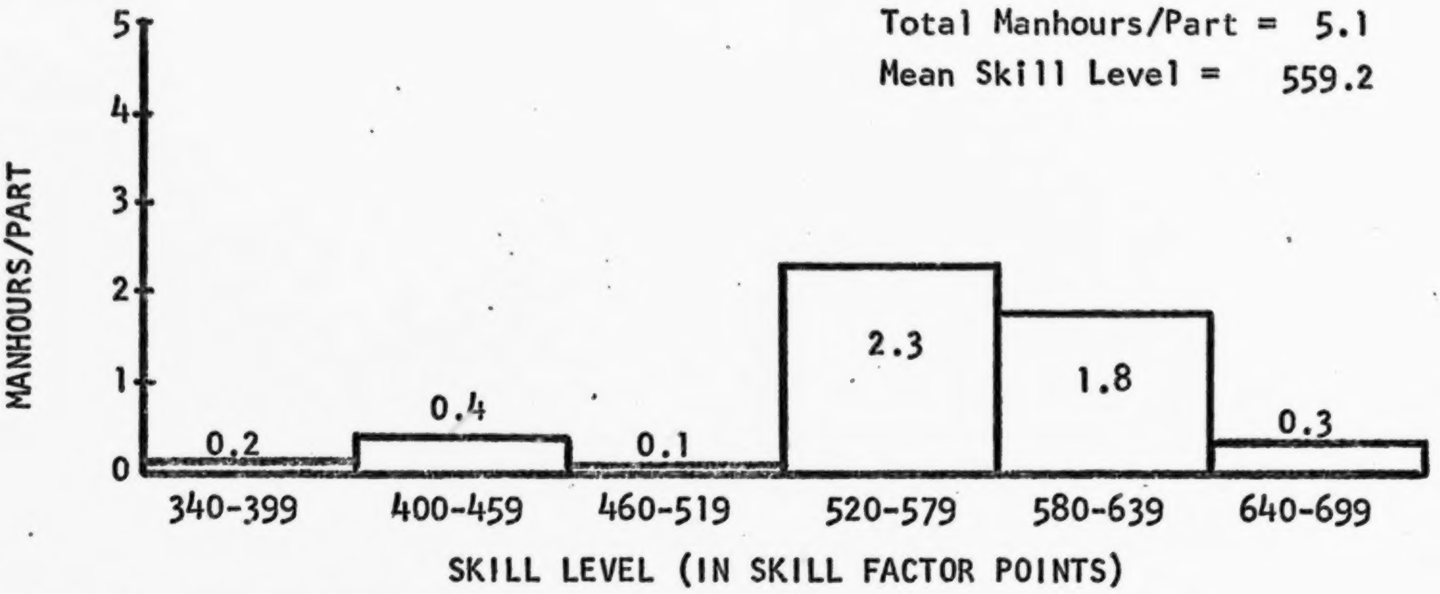


FIGURE IV-4: COMPARATIVE SKILL PROFILES FOR PART #502 (Firm E)
(excluded from data)

CONVENTIONAL MACHINING



N/C MACHINING



CHANGES - OLD TO NEW TECHNOLOGY

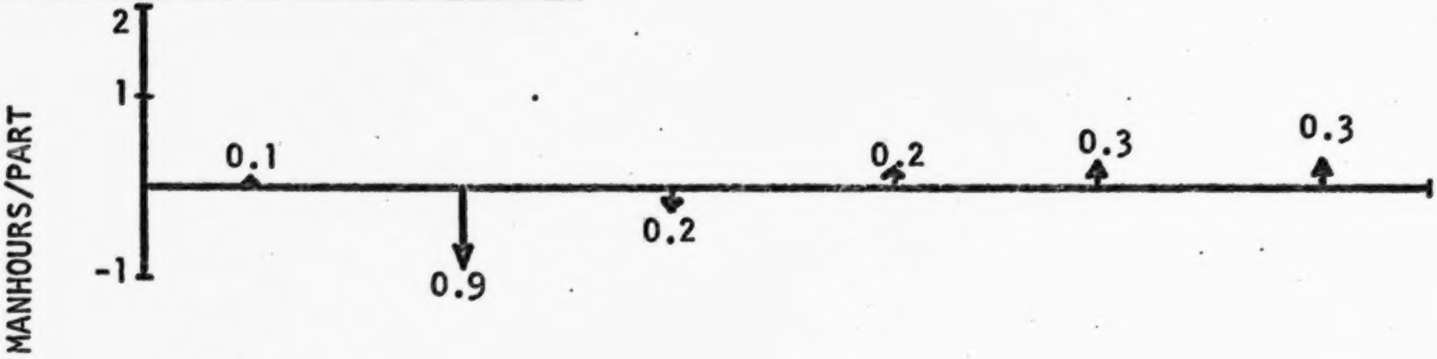
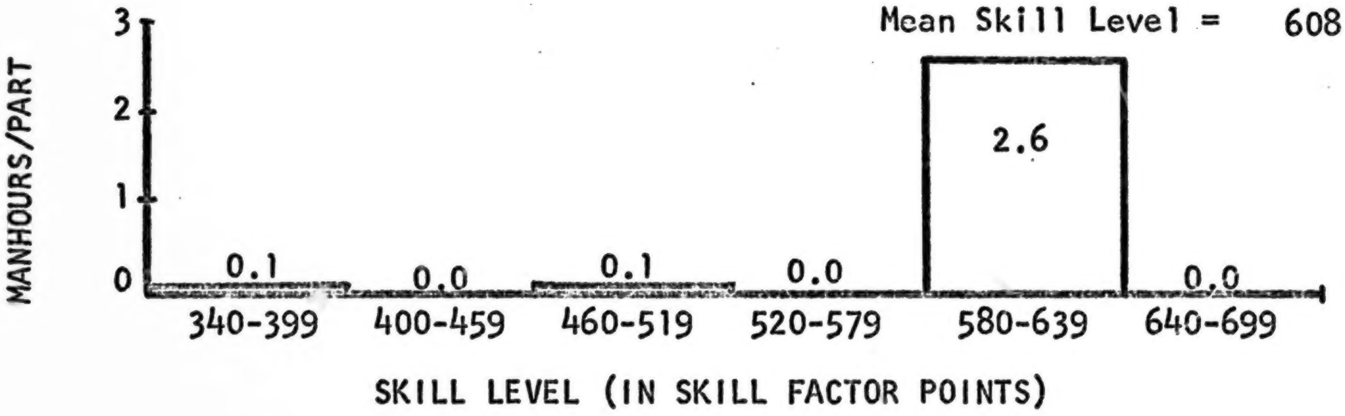


FIGURE IV-5: COMPARATIVE SKILL PROFILES FOR PART #549 (Firm F)

CONVENTIONAL MACHINING

Total Manhours/Part = 2.8

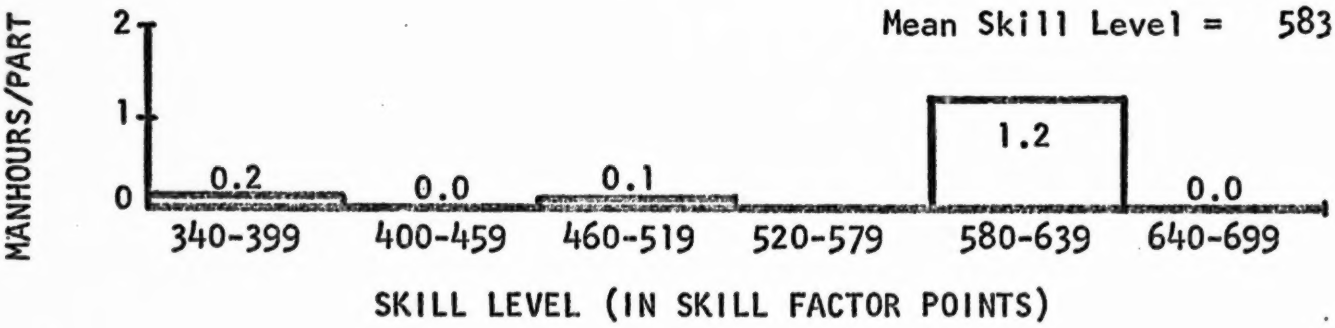
Mean Skill Level = 608.6



N/C MACHINING

Total Manhours/Part = 1.5

Mean Skill Level = 583.6



CHANGES - OLD TO NEW TECHNOLOGY

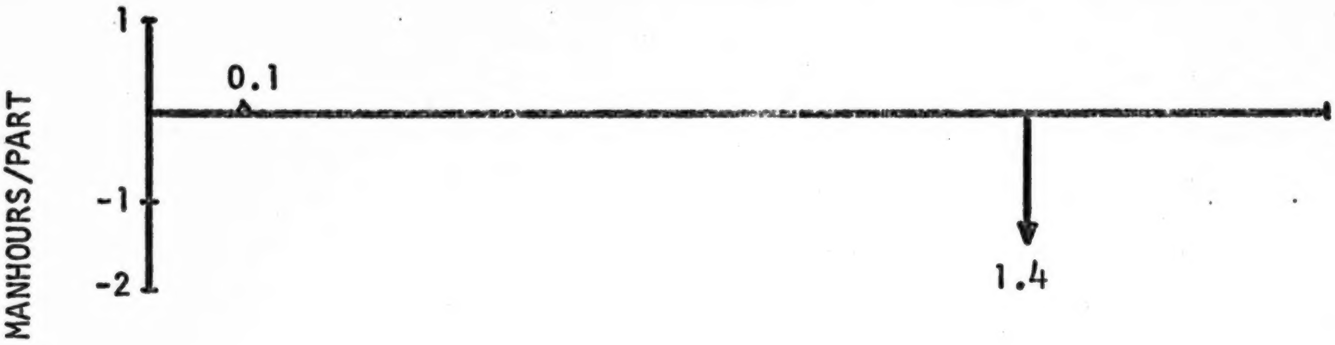
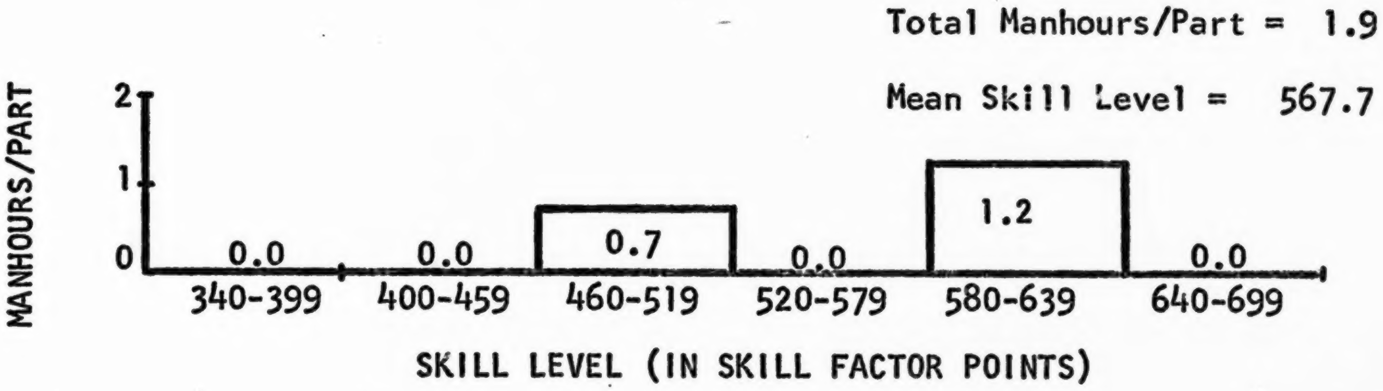
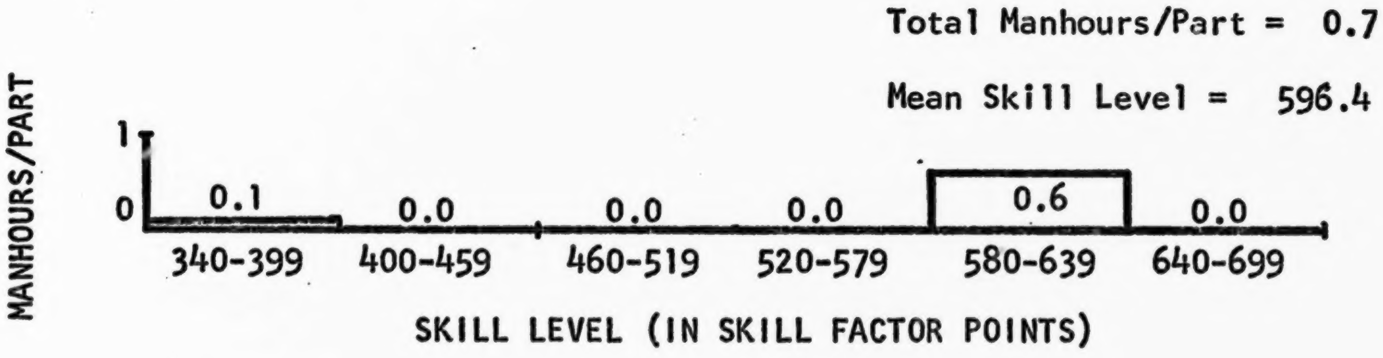


FIGURE IV-6: COMPARATIVE SKILL PROFILES FOR PART #398 (Firm F)

CONVENTIONAL MACHINING



N/C MACHINING



CHANGES - OLD TO NEW TECHNOLOGY

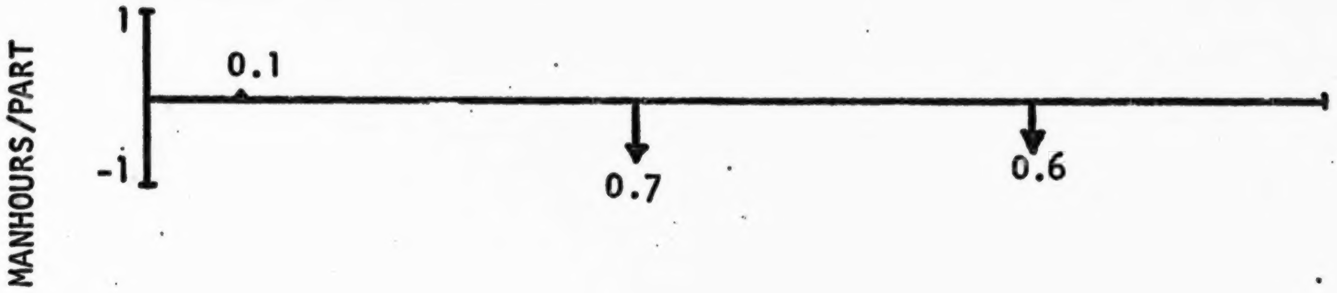
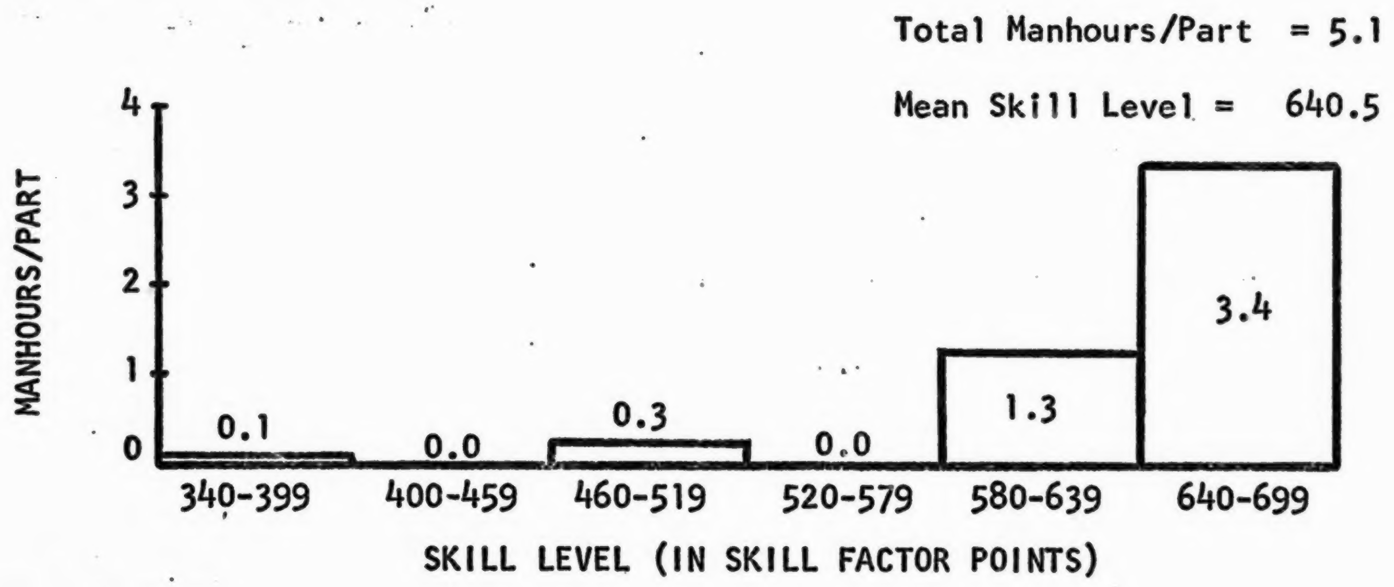
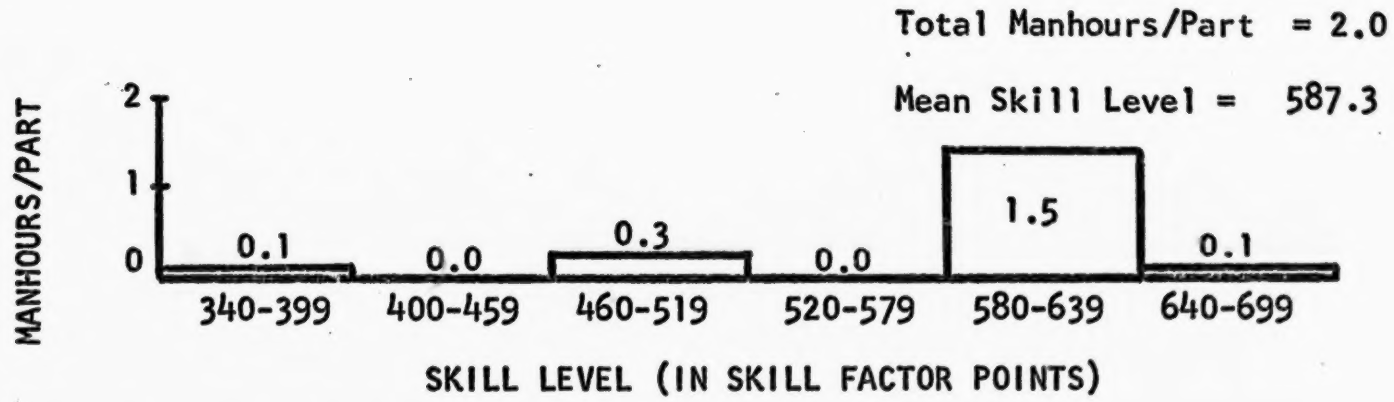


FIGURE IV-7: COMPARATIVE SKILL PROFILES FOR PART #601 (Firm F)

CONVENTIONAL MACHINING



N/C MACHINING



CHANGES - OLD TO NEW TECHNOLOGY

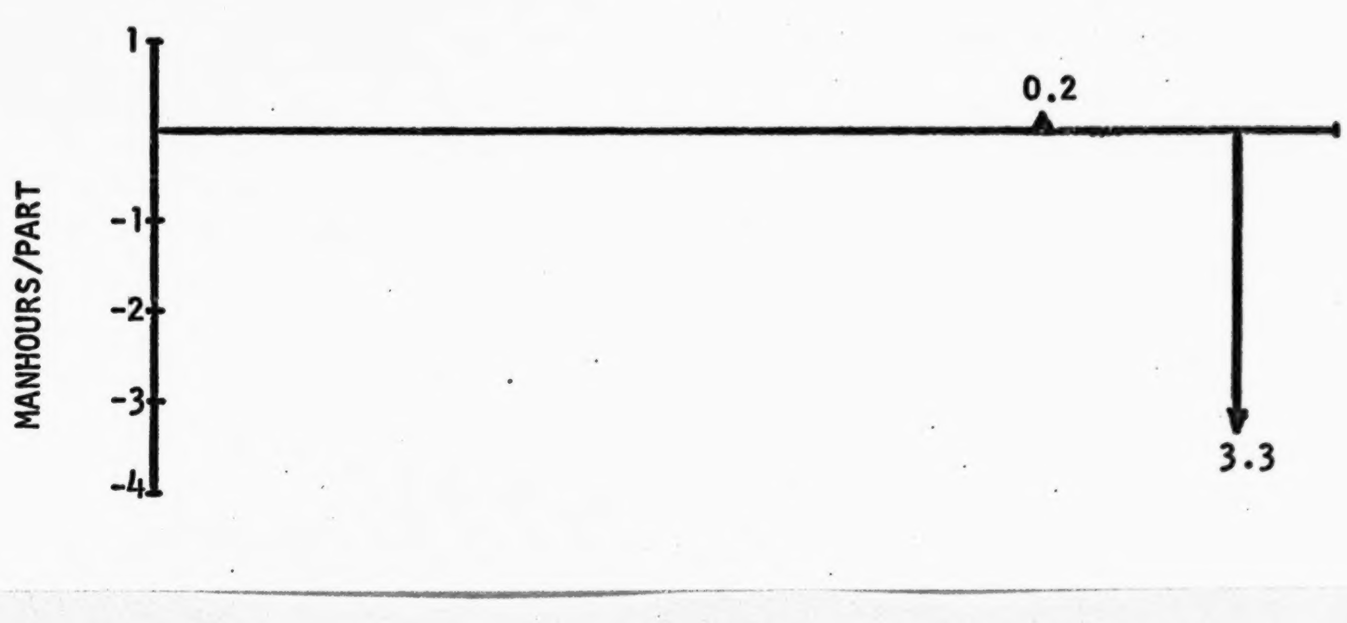
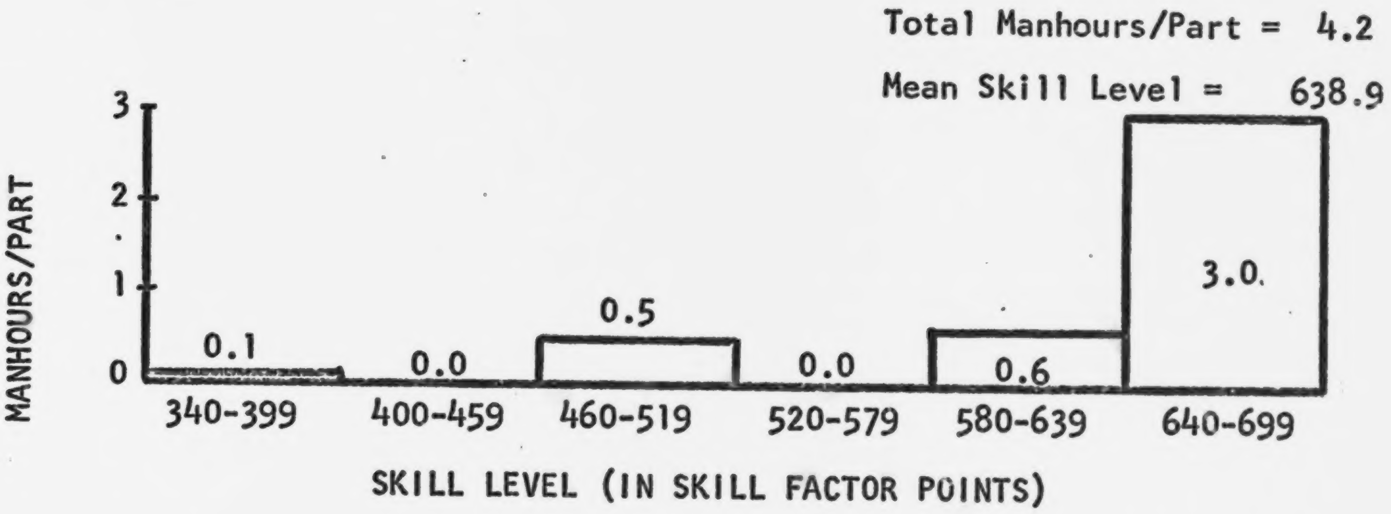
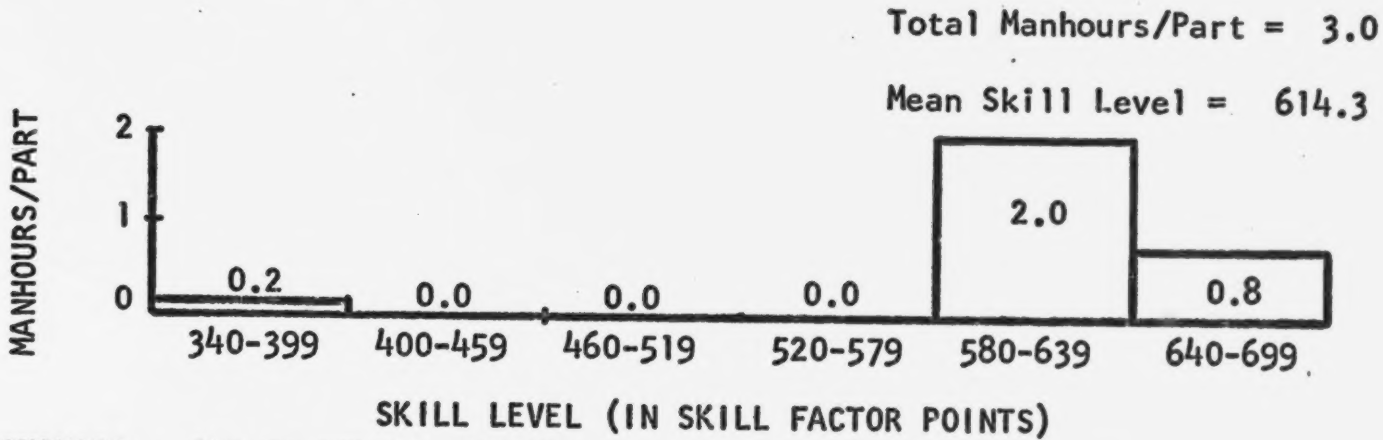


FIGURE IV-8: COMPARATIVE SKILL PROFILES FOR PART # 452 (Firm F)

CONVENTIONAL MACHINING



N/C MACHINING



CHANGES - OLD TO NEW TECHNOLOGY

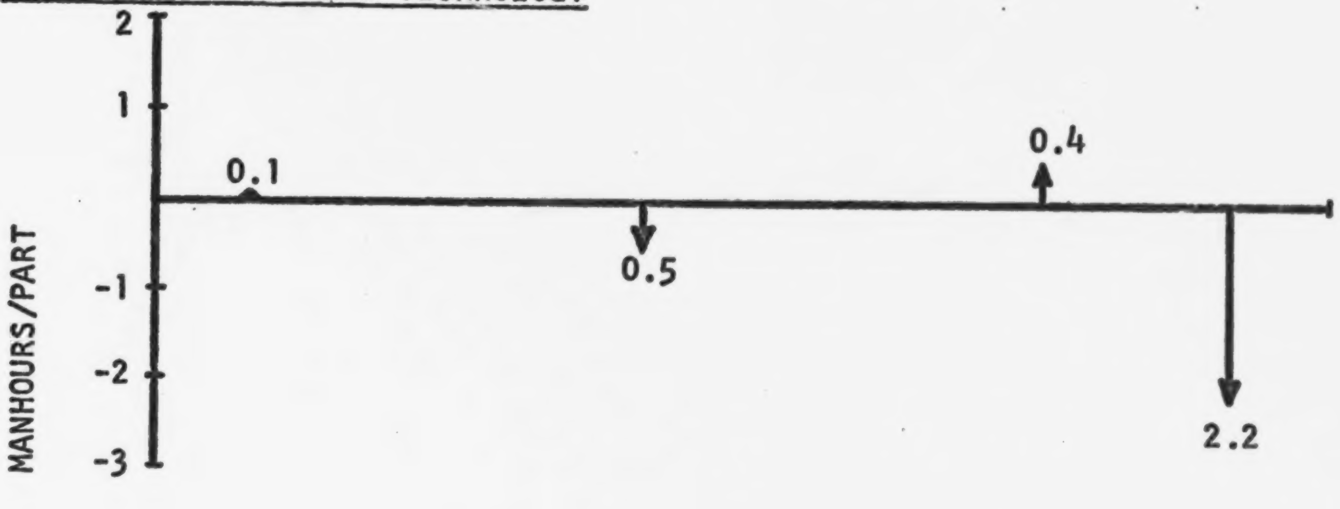
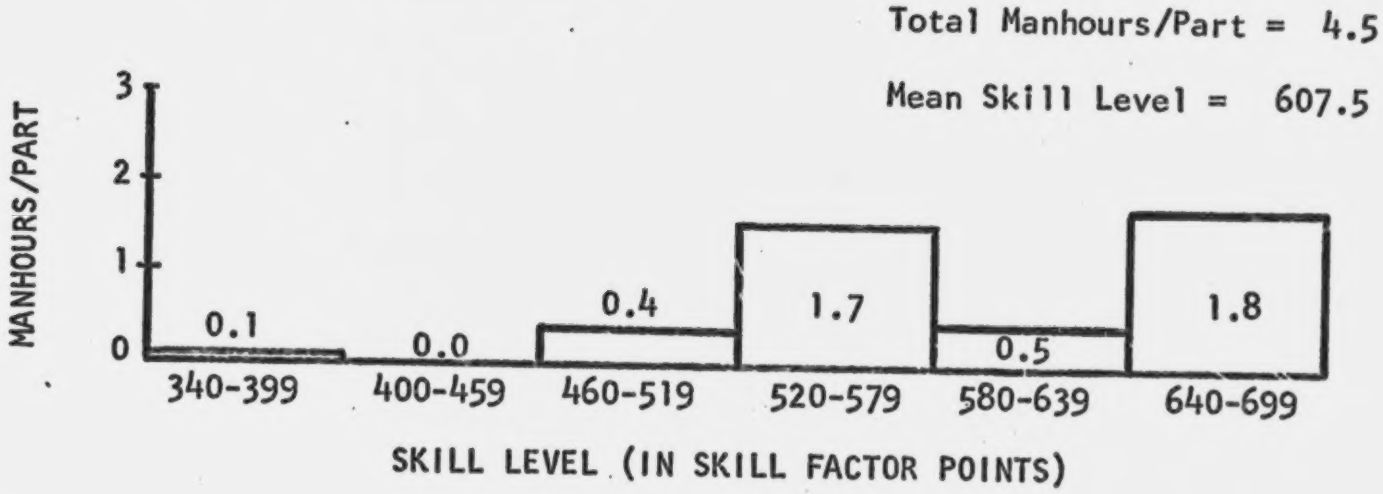


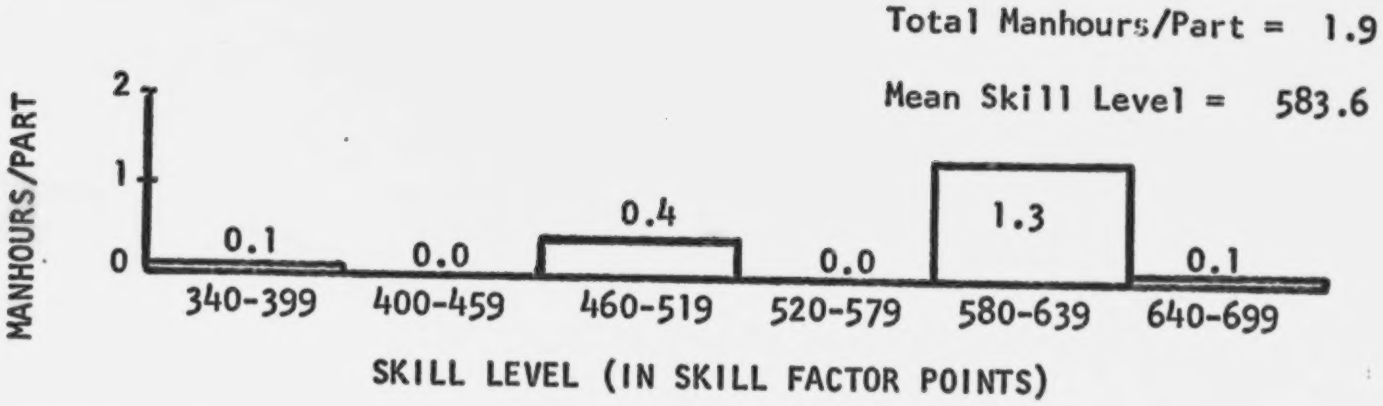
FIGURE IV-9: COMPARATIVE SKILL PROFILES FOR PART #389 (Firm F)

CONVENTIONAL MACHINING


Total Manhours/Part = 4.5

Mean Skill Level = 607.5

N/C MACHINING


Total Manhours/Part = 1.9

Mean Skill Level = 583.6

CHANGES - OLD TO NEW TECHNOLOGY

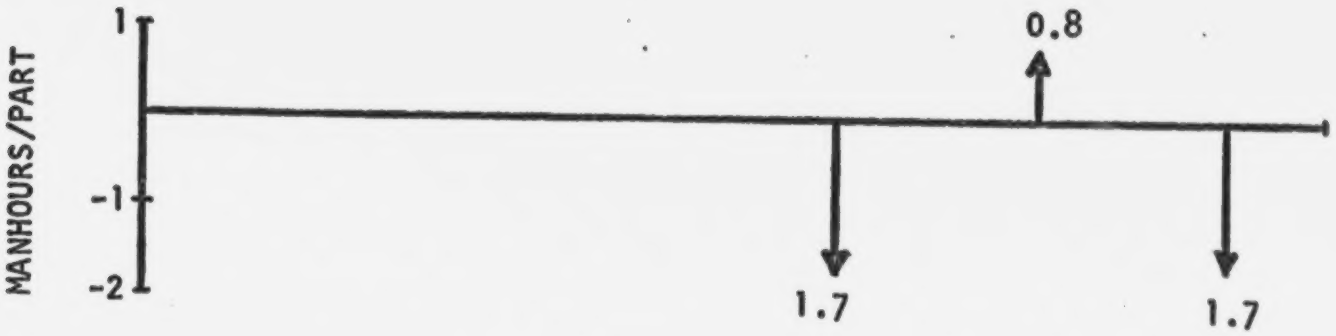
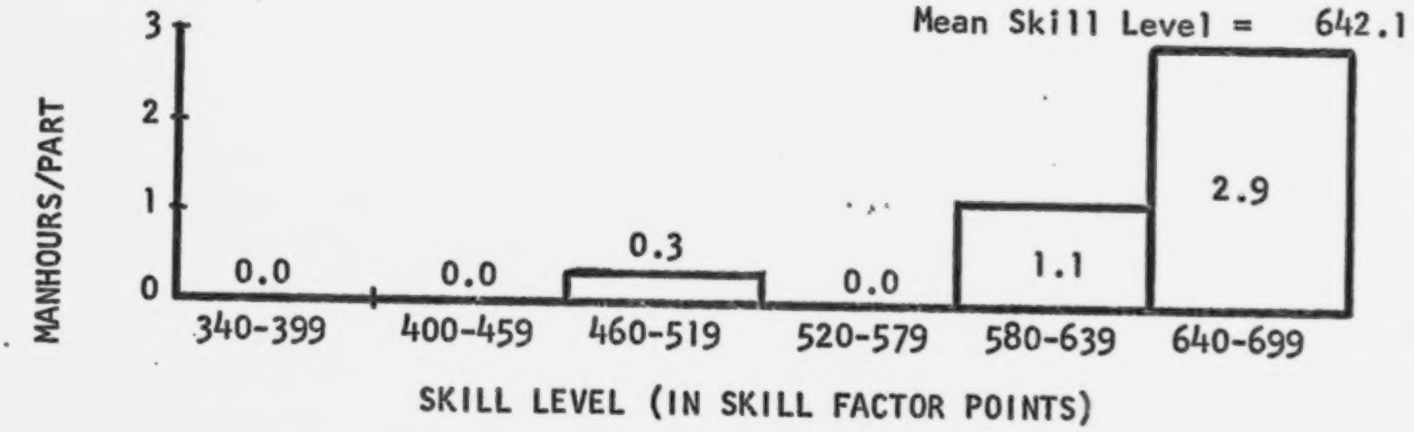
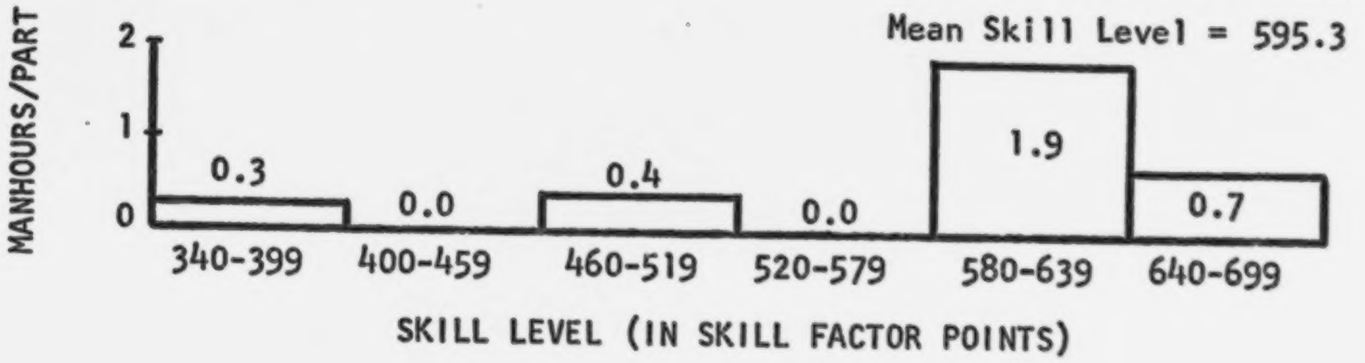


FIGURE IV-10: COMPARATIVE SKILL PROFILES FOR PART #884 (Firm F)

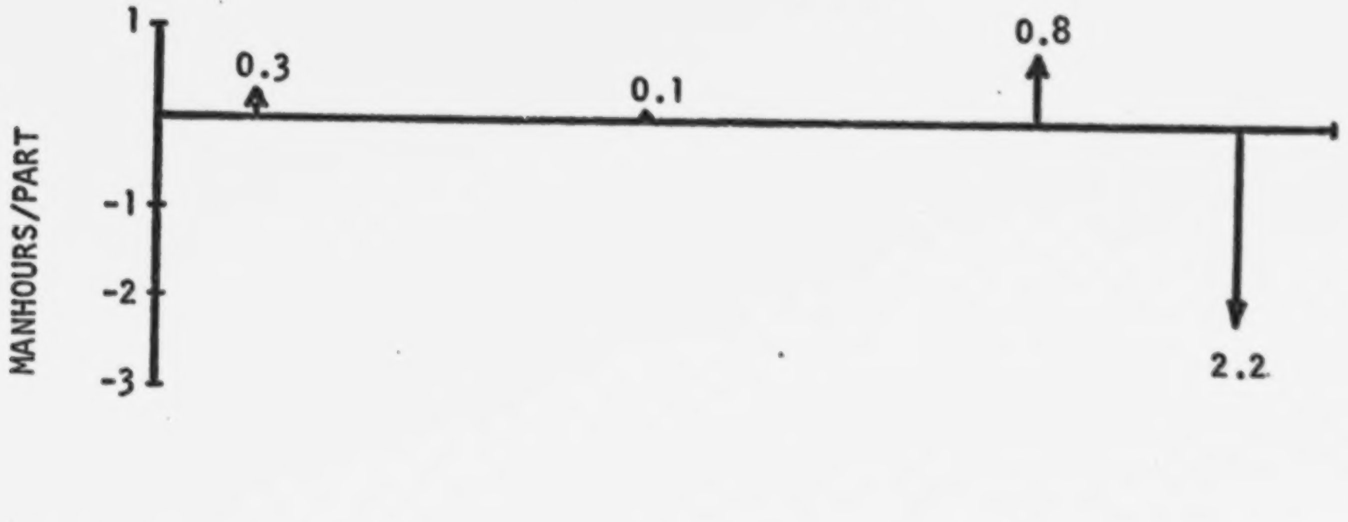
CONVENTIONAL MACHINING


Total Manhours/Part = 4.3
Mean Skill Level = 642.1

N/C MACHINING


Total Manhours/Part = 3.3
Mean Skill Level = 595.3

CHANGES - OLD TO NEW TECHNOLOGY



10. ANALYSIS OF VARIANCE LAYOUT OF DATA AND DETAILED SUMMARY

Improved estimate of residual variance was obtained by pooling the sums of squares and the degrees of freedom of the original residual estimate of the T x P interaction. The mean squares of the SL x T and SL x P interactions and of the main effects were tested against this improved estimate.

Key to abbreviations:

D.F. - Degrees of freedom
S.S. - Sums of squares
M.S. - Mean squares
V.R. - Variance ratio

SL - Skill levels
T - Technology levels
P - Parts

TABLE IV-16

Manhours per unit product classified by skill level, parts and technology

	Technology 1								Technology 2							
Skill Level	Part 1	Part 2	Part 3	Part 4	Part 5	Part 6	Part 7	Part 8	Part 1	Part 2	Part 3	Part 4	Part 5	Part 6	Part 7	Part 8
Low	0.38	0.11	0.07	0.09	0.12	0.04	0.02	0.05	0.36	0.01	0.20	0.10	0.14	0.06	0.25	0.17
Medium	0.19	2.00	0.45	2.12	0.26	0.74	0.33	0.07	0.14	1.02	0.00	0.41	0.26	0.00	0.40	0.07
High	1.81	3.00	3.59	2.24	4.64	1.21	4.07	2.60	1.44	2.41	2.72	1.42	1.59	0.60	2.57	1.21
Totals	2.38	5.11	4.11	4.45	5.02	1.99	4.42	2.72	1.94	3.44	2.92	1.93	1.99	0.66	3.22	1.45

TABLE IV-17 Analysis of Variance Summary

Source of Variance	D.F.	S.S.	M.S.	V.R.	Significance Level
Between skill levels	2	43.39	21.70	114.21	$P < 0.001$
Between technologies	1	3.34	3.34	17.58	$P < 0.001$
Between individual parts	7	4.80	0.69	3.63	$P < 0.05$
SL x T	2	2.89	1.45	7.63	$P < 0.01$
SL x P	14	10.22	0.73	3.84	$P < 0.01$
T x P	7	0.78	0.11	0.57	
Residual (SL x T x P)	14	3.24	0.23		
TOTALS	47	68.66			
Improved estimate residual	21	4.02	0.19		

11. JOB DESCRIPTIONS

E1: Conventional Machining of Components

Each job title is preceded by the internal job code. The number at the right margin is the skill factor point rating for the job.

E1-1 - Drill Press Operator - B 435

Sets up various types of drill presses (excluding radial drill presses), where operational sequences, set-up methods, tooling, speeds, and feeds are specified or established by shop practice. Positions parts correctly in jigs or fixtures and performs machining operations such as drilling, reaming, chamfering, spotfacing, counter boring, countersinking, etc. Works from planning sheets and templates. Sets, aligns and stakes bushings and bearings. Checks own work for conformance to specifications. Maintains good shop practice. Assists Drill Press Operator "A", as required.

E1-2 - Filer and Burrer - Machined Parts 455

Performs such operations as removing burrs, sharp edges and scratches and performs other filing and grinding operations on machined parts, such as grinding, fairing-in and blending radii, chamfering, etc., where moderate tolerances are involved. Improvises temporary tooling such as holding fixtures required in the set-up and operation of burring equipment, such as grinders, drill presses, etc. Selects, dresses and trues own abrasive wheels. Maintains good shop practice.

E1-3 - Milling Machine Operator - B 555

Operates various types of milling machines to perform such machining operations as squaring and truing material, cutting single angles, rough boring and straddle milling pads or bosses, slab and end milling, drilling, reaming, chamfering, serrating, slotting, elongating holes, cutting keyways, etc. Makes set-ups to perform such machining operations as face milling, cutting parts in half or to length and making clearance cuts. Changes speeds, feeds or cutting tools. Checks parts to specified dimensions using templates, blueprints, checking fixtures and/or precision measuring instruments. Makes adjustments when machine functions improperly or parts are not holding to required dimensions. Maintains good shop practice. Assists Milling Machine Machinist or Milling Machine Operator "A" as required.

E1-4 - Drill Press Operator - A 500

Plans the sequence of operations working from planning sheets, parts prints, templates and engineering change orders. Lays out reference lines and center points. Sets up various types of drill presses (excluding radial drill presses) without the aid of production tooling, improvising and adapting where necessary. Determines and sets proper speeds, feeds and depth of cut. Performs machining operations such as drilling, reaming, counter boring, tapping, chamfering, spotfacing, countersinking, etc. Works on tooling, production, and developmental parts. Performs rework, as required. Grinds own drills. Checks own work for conformance to specifications. Maintains good shop practice.

E1-5 - Hand Finisher - Precision - B 525

Performs close tolerance hand-finishing operations on machined parts, assemblies and weldments involving various radii, contours, angles, flanges, etc. Removes material by precision grinding, filing, and blending prior to final finishing. Performs final finishing where adequate tooling is provided. Selects, dresses and trues own abrasives. Checks own work for conformance to specifications. Maintains good shop practice. Assists Hand Finisher-Precision "A", as required.

E1-6 - Milling Machine Operator - A 615

Sets up various types of milling machines to perform production and/or tooling machining operations where operation sequences, materials and tooling are specified or established by previous shop practice, manufacturing outline sheet and/or blueprints. Positions and aligns holding fixtures, improvises and adapts special holding fixtures, selects proper cutting tools and sets and adjusts speeds, feeds and depth of cut. Lays out reference lines and center points as a guide in machining operations. Performs such operations as milling compound angles using established holding fixtures, milling multiple angles using indexing head, drilling equally spaced holes on a given circle using a rotary or dividing head, straddle milling, milling radii, serrating and keyway cutting. Checks own work for conformance to specifications. Maintains good shop practice. Assists Milling Machine Machinist, as required.

E1-7 - Radial Drill Press Operator - A 565

Plans sequence of operations to minimize amount of machining and numbers of set-ups required working from blueprints, sketches and other authorized documents. Lays out work where basic reference points are in more than one plane and are difficult to establish and coordinate. Sets up machine to perform any operation within its capacity by positioning, aligning and securing work, using specialized machine attachments, improvising and adapting tooling and other machining aids. Determines, sets and adjusts speeds and feeds. Selects and grinds tool bits and drills. Performs such machining operations as precision and/or angular drilling, reaming, boring, tapping, countersinking, spot-facing, etc., to exacting tolerances. Determines need for corrections during machining operations in order to obtain required finishes, hole locations, depth of cut and other specified requirements and makes necessary adjustments to accomplish the corrections. Checks own work for conformance to specifications. Maintains good shop practice.

E1-8 - Milling Machine Machinist 670

Plans the sequence of operations by determining operations to be performed, dimensions and tolerances, cutting tools to be used, method of holding and aligning work, and speeds and feeds. Locates and lays out reference lines, center points and center lines, computing angular and linear dimensions where required. Sets up machine to completely and independently perform any operation within its capacity. Machines highly variable tooling involving compound angles, concave and convex surfaces and/or complex production parts where difficult nature of tooling and/or parts requires ingenuity to improvise and adapt. Proves tooling, as required. Performs such operations as helical and spiral milling, serrating, gear, spline and keyway cutting and other operations requiring the use of a compound indexing or boring head attachment. Grinds own tool bits and drills. Works from templates, sketches, tool designs, etc. Checks own work for conformance to specifications. Maintains good shop practice.

E2: Numerically Controlled Machining

Each job title is preceded by the internal job code. The number at the right margin is the skill factor point rating for the job.

E2-1 - Burrer - Hand 396

Removes excess material, burrs, sharp edges, scratches, etc. on sheet metal parts, castings, forgings, etc. using files, scrapers, burring knives, countersinks, etc.

E2-2 - Filer and Burrer - Machined Parts 455

Same as that for Job E1-2.

E2-3 - Milling Machine Operator B 555

Same as that for Job E1-3.

E2-4 - Drill Press Operator A 500

Same as that for Job E1-4.

E2-5 - Hand Finisher - Precision B 525

Same as that for Job E1-5.

E2-6 - Drilling Machine Operator - Numerical Control 565

Uses pre-determined methods and procedures of setting up, holding and machining parts working from blueprints, sketches, numerical control data and other authorized documents. Lays out reference lines, center lines or reference points and moves, positions and/or aligns machine tables manually as necessary for setup or operation. Sets up machines completely and independently to perform any operation within their capacity by positioning, aligning and securing work using specialized machine attachments, improvising and adapting tooling and other machining aids. Loads machine control media and makes required control settings and manually operates machines to align spindles with set-up targets. Makes required set-ups and tool changes as programmed and as specified by operational instructions. Observes machining progress and watches for functional variations in machines or control units and notifies supervision of malfunctions. Makes periodic checks on parts to insure dimensional accuracy such as drilling, reaming, boring, counterboring, tapping, milling, grooving, slotting, etc. Operates machines in test mode to assist programming personnel to operationally check machine control media for logic errors and during initial tool tryout. Checks own work for conformance to specifications. Performs rework, as required. Maintains good shop practice.

E2-7 - Milling Machine Operator - Numerical Control A 615

Sets up and operates numerically controlled milling machines to perform machining operations where operation sequences, set-up methods, materials, tooling, speeds and feeds are specified or established by programming on tape or cards, manufacturing outline sheets, blueprints, etc. Mounts project or standard holding fixture and set-up target to work table and mounts cutter to spindle. Loads machine control tape or cards and makes required control settings and manually operates machine to align spindle with set-up target using dial indicator, as required. Makes intermediate set-up and cutter changes as programmed and as specified by set-up instructions. Observes milling progress and watches for functional variations in machine or control unit, and notifies supervision of malfunctions. Makes periodic checks on parts to ensure dimensional accuracy to establish cutter change cycle. Sets up and operates equipment to perform close tolerance conventional milling operations such as milling compound angles using holding fixtures, milling multiple angles using indexing head, drilling equally spaced holes on a given circle using a rotary tool or dividing head, milling radii, keyway cutting, etc. Operates machine in test mode to assist programming personnel to operationally check machine control unit for logic errors, and during initial tool tryout. Checks work to verify that cutter is producing acceptable finish. Maintains good shop practice.

E2-8 - Milling Machine Operator - A 615

Same as that for Job E1-6.

F1: Conventional Machining of Components

Each job title is preceded by the internal job code. The bracketed number at the right margin is the skill factor point rating on the Firm F scale; the following number is the corresponding skill factor point rating on the Firm E scale.

F1-1 - Factory Helper General (77) 396

Assists in handling and positioning heavy materials and equipment, securing tool for set-up, helping in breaking down the set-ups, segregating tools and fixtures and returning to proper sources. Loads and unloads parts on and off machines. Removes scrap, shavings, chips from the machines and helps in keeping work areas, machines and equipment clean and in orderly condition. Numbers or hand stamps parts for identification, cleans and lubricates parts, de-burrs, sands, putties, masks and hand stencils.

F1-2 - Drill Press Operator - A (232) 500

Sets up various types of single and multiple spindle drill presses where tooling is inadequate and it is necessary to check parts for accuracy and coordination of dimensions using surface plates and/or precision measuring instruments. Mounts, centers, clamps or blocks jig or press table. Determines method of loading, aligning and fastening parts in jig. Makes set-ups using and improvising standard tooling and/or makes whole lay-outs as required. Selects, installs and adjusts cutting tools. Operates machine to perform operations such as drilling, reaming, boring, counter-boring, tapping, flycutting, spotfacing and back spotfacing to exacting tolerances and coordinated dimensions.

F1-3 - Duplicating and Profiling Machine Operator (290) 576

Sets up duplicating and profiling machines to reproduce parts where materials and tooling are provided and machining methods, operation sequences and tolerances have been predetermined. Mounts, fastens and aligns model, pattern or template. Selects and adjusts cutter and tracer, sets speeds, feeds and depth of cut. Scribes reference points and lines as a guide for aligning work with patterns, model or template. Operates automatic duplicating machines, such as Keller, Hydro-Tel or Trutrace equipped machines and manually operated duplicating machines.

F1-4 - Milling Machine Operator - A (314) 615

Makes complete set-up of milling machine to perform operations where materials, tooling, cutting tools, operation sequences and tolerances are established. Aligns and fastens work, mounts cutting tool, sets speeds, feeds and depths of cut. Grinds own tool bits other than special purpose tools. Lays out on parts reference lines and center points. Operates milling machine to perform such typical operations as milling compound angles, using established holding fixtures, milling multiple angles using indexing head, drilling equally spaced holes on a given circle using a rotary table or dividing head, milling radii, serrating spline and keyway cuttings to close tolerances.

F1-5 - Engine Lathe Operator - A (314) 615

Makes complete set-up of engine lathe to perform machine operations where operation sequences, materials and tooling are established. Centers and fastens work using chuck, collet, face-plate or holding fixture. Mounts cutting tools, sets feeds and speeds, makes all necessary machine adjustments. Grinds own tool bits and simpler types of special purpose tools. Lays out on parts reference lines and center points. Operates lathe to perform such operations as turning, profile turning, chasing, drilling, boring, grooving, reaming, chamfering and tapping; thread cutting all types of threads by use of taps and dies; cutting straight or tapered single lead thread by use of a single cutting tool; and machining single angles and radii to close tolerances.

F1-6 - Milling Machine Machinist (393) 670

Plans sequence of machining operations, number of cuts required to obtain required finishes and tolerances, method of set-up. Makes complete lay-out on parts involving compound angles and exacting muting part work. Sets up completely and independently any plane or universal horizontal or vertical milling machine by selecting, mounting and aligning various specialized machine attachments and standard or improvised tooling. Works on highly variable and non-repetitive tooling, experimental and maintenance parts and/or complex production parts requiring exacting and coordinated tolerances and multiple set-ups. Performs such difficult operations as machining compound angles and contours, boring compound angular holes, and doing helical and spiral milling, serrating, gear spline and keyway cutting and other operations requiring the use of a compound indexing or boring head attachment. Profiles cams and tracers and cuts all sizes of concave and convex surfaces to templates using a duplicating attachment. Other operations include drilling, boring or reaming coordinated holes, dove-tailing, slotting, counterboring, and face, straddle or gang milling to exacting tolerances.

F1-7 - Duplicating and Profiling Machinist (393) 670

Plans sequence of machining operations to minimize warpage, number of cuts required to obtain required finish and tolerance, method of holding, aligning and coordinating the part and master. Lays out inscribed reference lines and points on part and model for proper positioning and alignment. Sets up duplicating machines by selecting, mounting, positioning and fastening part and model or template in proper relation, or selecting, mounting and aligning various specialized machine attachments and standard or improvised tooling. Selects, mounts and fastens cutting tools and/or tracers. Determines, sets and adjusts machine speeds, feeds and depth of cut. Grinds own tool bits, drills and traces. Performs such difficult operations (without patterns, models or templates) as locating and boring holes, case milling, slotting, grooving to exacting tolerances. Machines irregular surfaces not adaptable to a milling machine.

F1-8 - Jig Borer Machinist (393) 670

Determines the sequence of all operations working from tooling blueprints. Makes supplemental lay-outs and charts as required. Sets up machines, aligns and secures work on table, selects and mounts tools, positions table according to chart, determines, sets and adjusts feeds, speeds and stops. Grinds own tool bits and drills. Operates a jig borer to perform such difficult operations as reaming and straight and angle boring where exacting tolerances and coordinated dimensions are required.

F2: Numerically Controlled Machining

Each job title is preceded by the internal job code. The bracketed number at the right margin is the skill factor point rating on the Firm F scale; the following number is the corresponding skill factor point rating on the Firm E scale.

F2-1 - Factory Helper General (77) 396

Job description as for F1-1.

F2-2 - Drill Press Operator - A (243) 500

Job description as for F1-2.

F2-3 - Milling Machine Operator - A (314) 615

Job description as for F1-4.

F2-4 - Engine Lathe Operator - A (314) 615

Job description as for F1-5.

F2-5 - Numerical Control Milling Machine Operator (314) 615

Works from engineering drawings, machine set-up charts and instructions and shop orders. Mounts holding fixtures, positions, aligns and clamps work on table, mounts cutter to spindle. Loads machine control tape, checks and makes required control settings. Manually operates machine to align spindle and coordinate with tape and places machine in automatic machining cycle. Observes milling progress and operates feed rate override control as necessary to prevent spindle overload and to obtain specified machine finish. Scans gauge and console readings periodically making necessary operating adjustments. Makes required set-ups in cutter changes as programmed on control tapes during automatic machining cycle. Operates machine manually during unprogrammed cutter and fixture changes as required.

F2-6 - Milling Machine Machinist (393) 670

Job description as for F1-6.

F2-7 - Lathe Machinist (393) 670

Plans the sequence of machining operations and determines cutting tools to be used and method of holding and aligning work. Makes complete lay-outs on parts involving compound angles and exacting mating part work. Computes angular and linear dimensions as required. Sets up machine, centers and fastens work in machine using chuck, collet, face or angle plate or improvised tooling. Selects, mounts and fastens cutting tool, determines, sets and adjusts machine feed and speeds. Grinds own tool bits and drills. Works on unusual and irregular shaped castings, forgings and parts requiring ingenuity in improvising and adapting standard tooling, or on long parts, requiring exacting tolerances and concentricity. Operates the machine to perform such difficult operations as chasing all types of single and multiple external and internal threads with a single tool, turning external and internal tapers, turning and boring for any type of machine fit and machining parts involving compound angles or concentric and coordinated concave or convex surfaces to exacting tolerances.

F2-8 - Jig Borer Machinist (393) 670

Job description as for F1-8.